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Department of the Environment, London (England)

Prepared for

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FINAL REPORT
ON THE
ADVANCED WASTEWATER TREATMENT PROJECT
TO THE
NATO COMMITTEE ON THE CHALLENGES OF
MODERN SOCIETY.

THE NORTH ATLANTIC TREATY ORGANISATION

VOLUME 2

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WATER ENGINEERING DIRECTORATE

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STEVENAGE LABORATORY EVALUATION OF COAGULANT CHEMICALS

APPENDIX A1

Coagulant Dose (mg/l)	Coagulant Cost (p/m³) (1973)	pH	Values (mg/m) and removals (%) SS		BOD₅		COD		Thickened sludge Volume (mg/l)	Dry solids (%)	Specific resistance (10^{12} m/kg)
FERRIC CHLORIDE											
Raw wastewater		7.5	608		383		940		–	–	–
0	–	7.5	147	76	275	28	535	43	9	3.5	25
50	0.7	7.1	33	95	185	52	306	67	16	3.6	63
100	1.4	6.8	24	96	140	64	310	67	21	2.8	31
200	2.8	6.4	6	99	133	65	262	72	24	2.1	34
400	5.6	5.8	60	90	150	61	34	67	35	2.2	19
ALUMINIUM SULPHATE											
Raw wastewater		7.9	572		417		970		–	–	–
0	–	7.9	164	72	264	37	445	54	12	3.7	28
50	0.2	7.5	102	82	175	58	366	62	14	2.8	60
100	0.5	7.3	68	88	160	62	398	59	21	2.6	63
200	1.0	7.1	19	97	167	60	272	72	31	2.0	44
400	1.9	6.5	14	98	140	67	230	76	42	1.8	13
LIME											
Raw wastewater		7.9	474		567		960		–	–	–
0	–	7.9	134	76	250	56	390	44	8	3.9	27
50	0.04	8.6	118	75	190	67	355	63	10	4.5	39
100	0.08	9.1	30	92	113	80	260	73	12	7.5	44
200	0.16	9.4	35	93	113	80	256	73	13	4.7	50
300	0.23	9.8	23	95	90	84	226	77	14	8.7	20
600	0.46	11.8	20	96	120	79	275	71	28	5.0	5
500 mg/l LIME PLUS FERRIC CHLORIDE											
Raw wastewater			327				745				
lime only	0.40		28	91			276	63			
lime +2.5mg/l	0.43		25	92			286	62			
lime + 5mg/l	0.47		21	94			284	62			
lime + 10mg/l	0.54		24	92			262	65			
lime +15mg/l	0.71		10	97			240	68			
500 mg/l LIME PLUS 0.1 mg/l POLY-ELECTROLYTES											
Raw wastewater			452				1080				
Lime only			78	83			300	72			
+ Hercofloc			100	78			370	66			
+ Magnafloc			96	79			450	59			
+ Polyflok 95AP			102	78			375	66			
+ Polyflok 80NP			94	79			445	58			
+ Polyflok 61CP			78	98			415	62			

Notes
Supplier of Chemicals
Hercofloc – Hercules Powder Co., London
Magnafloc – Allied Colloids, Bradford
Polyflok 95AP) Yorkshire
Polyflok 80NP)Chemicals
Polyflok 61CP) YOC Reagents Division, Leeds.

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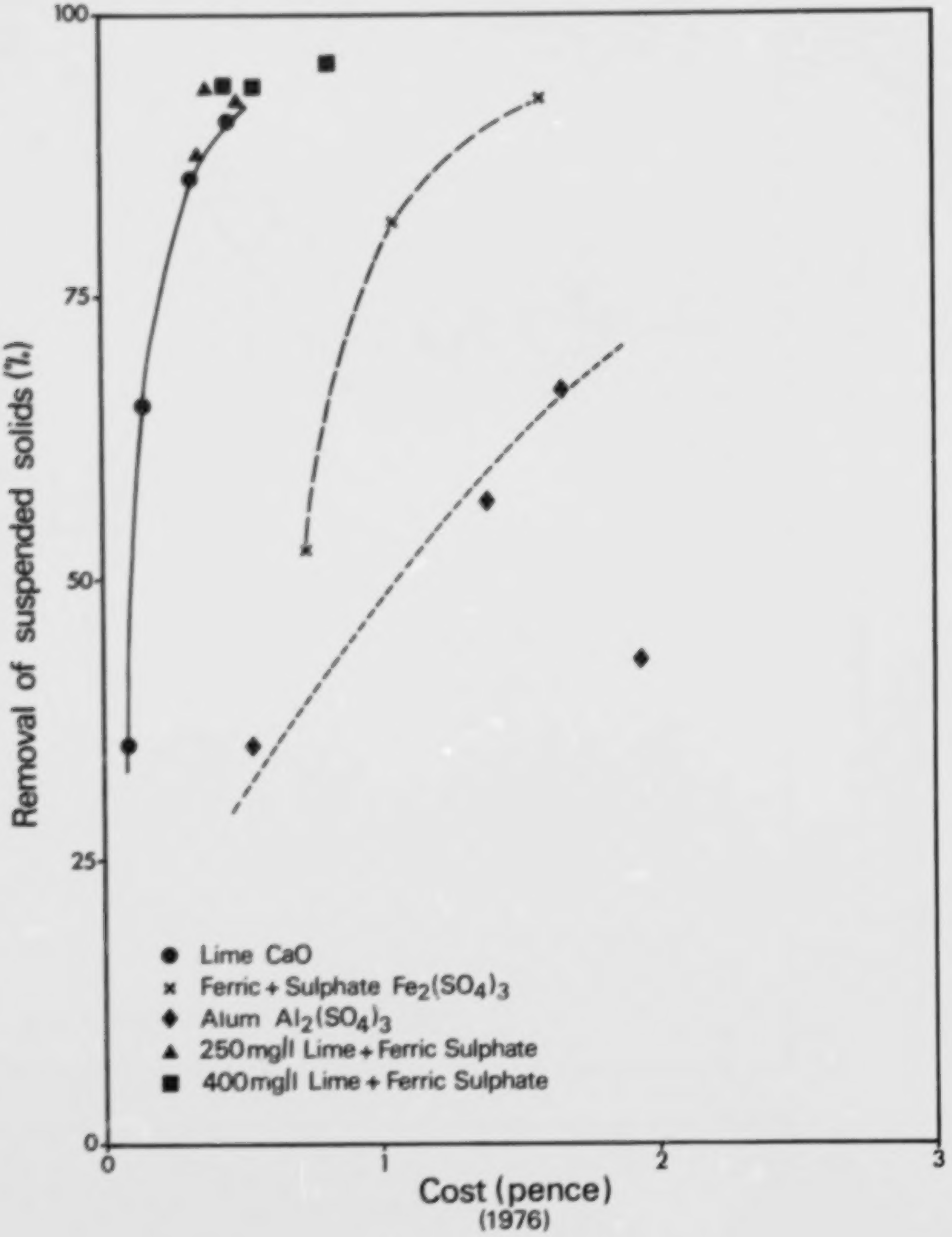
* doses as $FeCl_3$, $Al_2(SO_4)_3$, and CaO respectively

COLEHILL PILOT PLANT: EVALUATION OF COAGULANT CHEMICALS — APPENDIX A 2

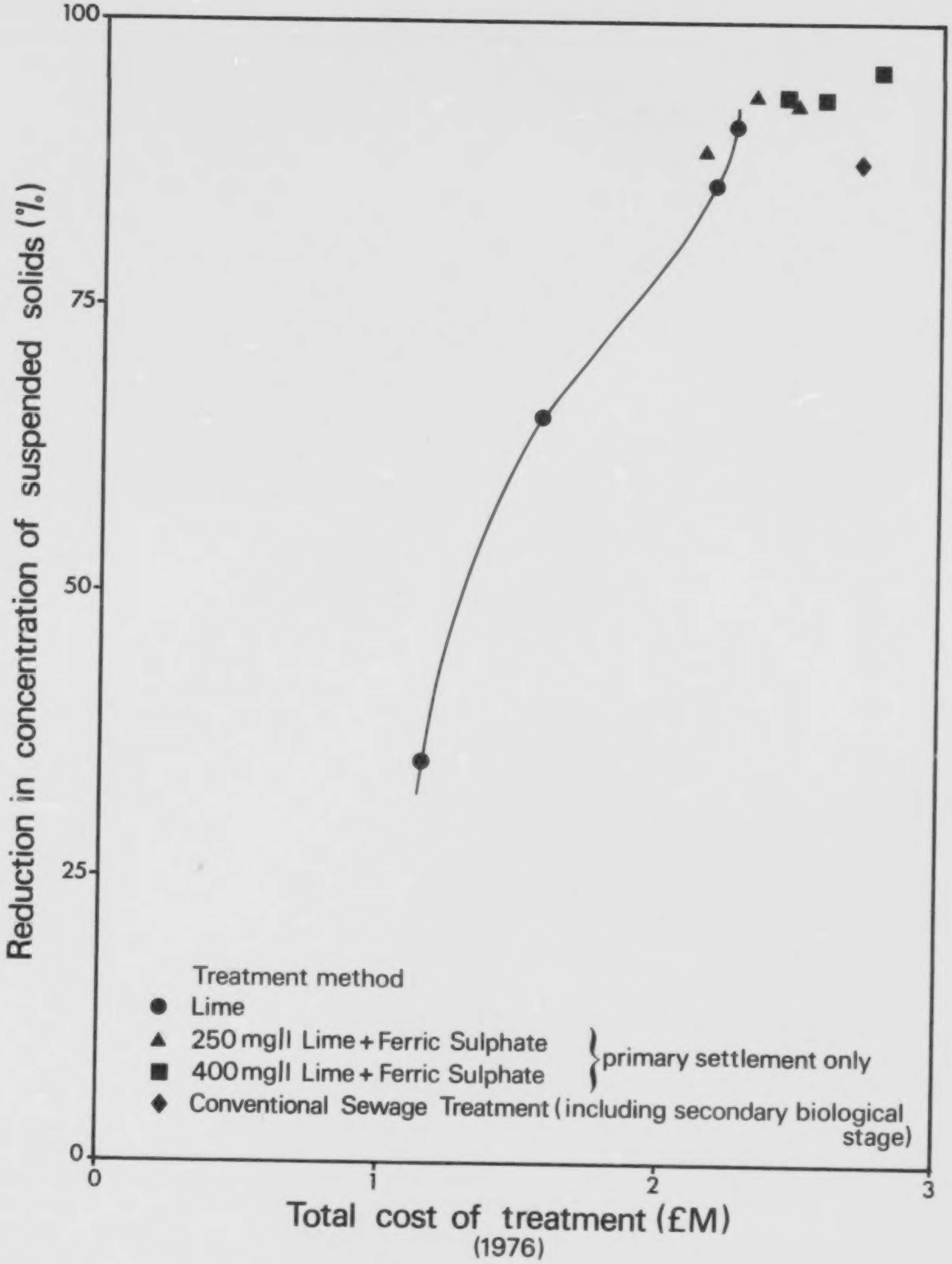
COAGULANT and feed	pH	Values (mg/l) and removals (%)			Thickened sludge		
		SS	BOD_5	Ortho-phosphate	Volume (mg/l)	dry solids (mg/l)	Specific resistance (10^{12} m/kg)
NO COAGULANT (retention 2h)							
Raw wastewater	7.3	275	212	6.5			
Tank effluent	7.2	185	180	6.1			
		33	15	6			
FERRIC SULPHATE							
Raw wastewater	6.8	198	231	7.7			
Dose 35 mg/l	6.5	95	115	2.3	0.26	1.9	23
		52	50	70			
Raw wastewater	6.8	176	206	7.2			
Dose 50 mg/l	6.2	32	79	0.6	0.32	2.0	21
		82	62	92			
Raw wastewater	6.9	189	206	6.5			
Dose 75 mg/l	5.6	15	55	0.1	0.27	1.0	15
		92	74	99			
ALUMINIUM SULPHATE							
Raw wastewater	7.2	249	240	6.4			
Dose 20 mg/l	6.9	97	180	4.4			
		62	25	21			
Raw wastewater	7.0	224	215	6.4			
Dose 50 mg/l	6.4	70	118	2.2	0.23	2.6	20
		69	45	66			
Raw wastewater	7.1	208	219	5.5			
Dose 60 mg/l	6.0	170	97	1.0	0.18	1.9	7
		19	56	82			
Raw wastewater	7.1	271	259	7.6			
Dose 70 mg/l	6.0	185	126	2.5	0.19	2.1	6
		32	51	67			
LIME							
Raw wastewater	7.0	206	192	5.0			
Dose 100 mg/l	9.3	120	148	2.1	0.19	2.7	5
		42	23	58			
Raw wastewater	7.1	196	184	4.9			
Dose 200 mg/l	10.6	43	102	1.1	0.49	7.2	11
		79	45	78			
Raw wastewater	7.0	205	152	5.3			
Dose 250 mg/l	10.8	46	88	0.4			
		78	42	92			
Raw wastewater	7.0	214	217	7.9			
Dose 300 mg/l	10.9	21	66	0.2	0.69	5.1	9
		91	70	98			
Raw wastewater	7.0	250	219	7.9			
Dose 350 mg/l	11.1	30	111	0.7			
		88	49	92			
Raw wastewater	7.0	258	222	7.5			
Dose 400 mg/l	11.2	28	70	0.1	0.61	4.6	6
		90	69	99			
250 mg/l LIME PLUS FERRIC SULPHATE							
Raw wastewater	7.0	205	152	5.3			
Lime only	10.8	46	88	0.4			
		78	42	92			
Raw wastewater	7.0	204	283	6.3			
Lime + 5 mg/l	10.7	24	111	0.5	0.62	4.1	–
		88	41	92			
Raw wastewater	6.9	210	231	8.2			
Lime + 10 mg/l	10.6	14	102	0.5	0.64	4.6	–
		93	56	94			
Raw wastewater	6.9	203	185	6.1			
Lime + 15 mg/l	9.9	17	78	0.5	0.61	4.3	3
		16	58	92			
400 mg/l LIME PLUS FERRIC SULPHATE							
Raw wastewater	7.0	258	222	7.5			
Lime only	11.2	28	70	0.1			
		89	68	99			
Raw wastewater	7.0	184	241	6.2			
Lime + 5 mg/l	11.1	13	92	0.5	0.67	3.0	5
		93	62	92			
Raw wastewater	7.0	256	253	6.4			
Lime + 10 mg/l	11.2	17	74	0.5	0.63	3.2	5
		93	71	92			
Raw wastewater	7.4	197	260	5.6			
Lime + 15 mg/l	11.2	9	132	0.5	0.86	2.3	5
		95	49	91			

OPERATIONAL DATA

Flowrate	450 m^3/d steady	Settling tank upward flow rate	2.7 m/h
Chemical dosing method	proportional to flow	Sludge recirculation	none
Flashmixer detention	12 minutes	Source of figures	average over periods noted below
Flocculator detention	40 minutes		
Settling tank detention	1.1 h	Period of experiment	at least 1 week for each chemical or combination of chemicals



Cost of chemicals in pence per m^3 of wastewater treated at Coleshill pilot plant.



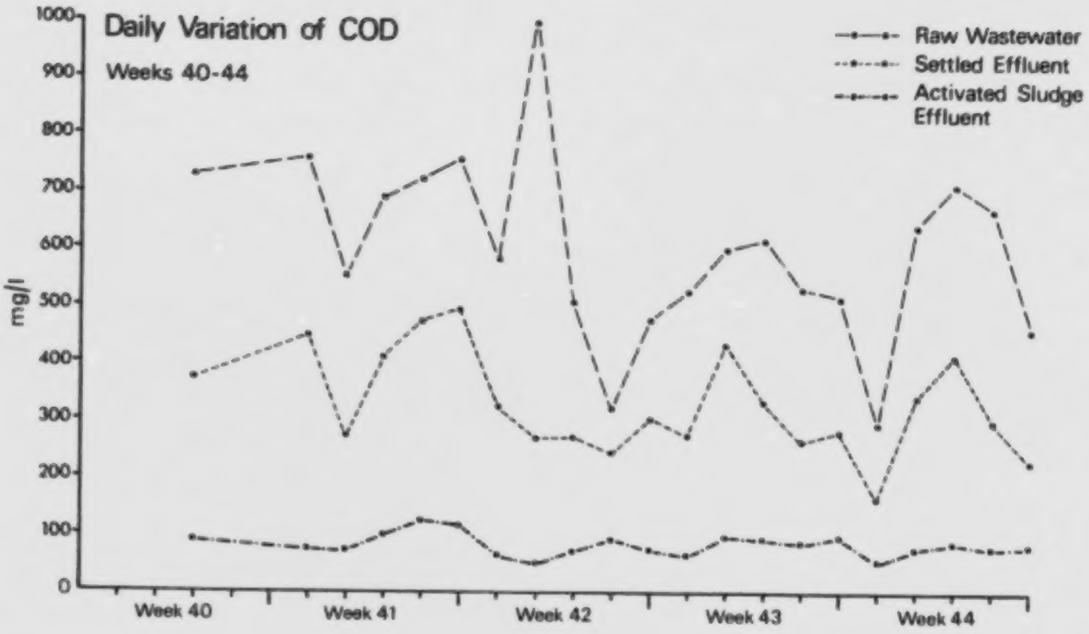
Notional costs of treating 45000 m^3/d of wastewater (including sludge de-watering by filter press)

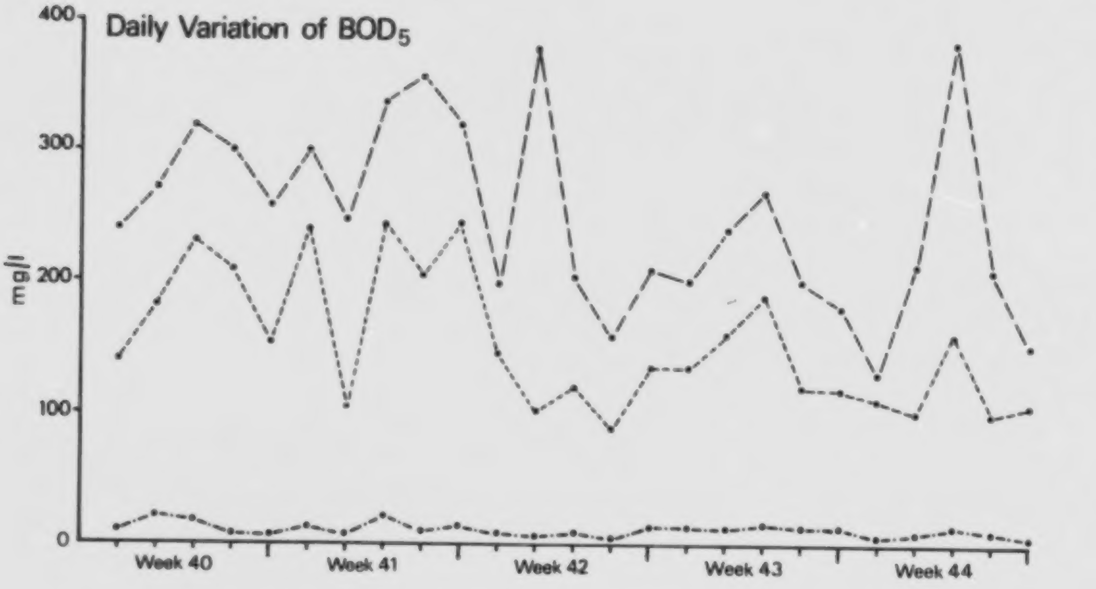
LIME-AIDED SETTLEMENT ON THE STEVENAGE, DAVYHULME AND COLESHILL PILOT PLANTS

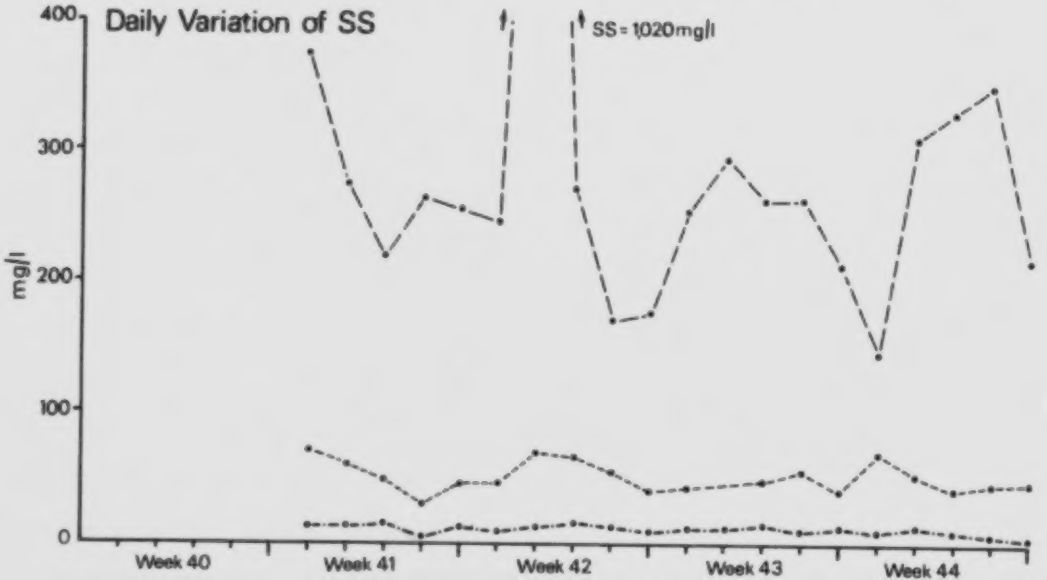
APPENDIX A5

Degree of liming of wastewater before tank treatment		STEVENAGE			DAVYHULME			COLESHILL		
		Raw waste-water	Tank effluent	% Removal	Raw waste-water	Tank effluent	% Removal	Raw waste-water	Tank effluent	% Removal
NO LIMING										
pH					7.2	7.2	–	7.3	7.4	–
SS	mg/l				472	196	58	185	145	12
BOD_5	mg/l				250	182	25	205	191	8
COD	mg/l				892	568	36	526	458	23
PO_4	mg/l				5.9	4.9	17	4.5	5.1	15
Sludge										
kg/m^3 of wastewater						0.006				
dry solids %						3.3				
LIMING TO pH 10										
pH		7.7	10.3	–	7.0	9.1	–	7.1	9.2	–
SS	mg/l	430	264	39	518	106	80	254	138	46
BOD_5	mg/l	493	246	50	324	177	43	222	168	24
COD	mg/l	1207	487	60	882	371	58	506	395	22
PO_4	mg/l	12.2	5.4	56	3.9	0.5	87	11.4	6.4	44
Sludge										
kg/m^3 of wastewater			1.07			0.48				
dry solids %			3.0			3.5				
LIMING TO pH 10.5										
pH		7.9	10.4	–	7.4	9.6	–	7.1	10.0	–
SS	mg/l	309	199	36	327	54	85	196	68	65
BOD_5	mg/l	408	266	35	272	164	40	190	123	35
COD	mg/l	887	521	41	635	354	44	504	243	52
PO_4	mg/l	10.7	4.7	56	2.8	0.7	75	10.2	3.0	75
Sludge										
kg/m^3 of wastewater			0.94			0.62			0.48	
dry solids %			2.7			4.6			5.8	
LIMING TO pH 11										
pH		7.8	11.0	–	8.0	10.3	–	7.1	10.7	–
SS	mg/l	198	59	70	315	62	80	216	32	85
BOD_5	mg/l	303	158	48	290	198	32	173	82	53
COD	mg/l	585	273	63	756	420	44	509	157	69
PO_4	mg/l	14.6	0.9	94	3.8	0.9	76	8.7	0.4	95
Sludge										
kg/m^3 wastewater			1.03			0.54			0.62	
dry solids %			2.9			4.3			5.0	
LIMING TO pH 11.5										
pH		7.5	11.5	–	8.1	11.1	–	7.2	11.2	–
SS	mg/l	212	27	87	321	66	79	219	30	86
BOD_5	mg/l	297	138	64	286	193	33	173	82	53
COD	mg/l	548	252	64	760	388	49	509	157	69
PO_4	mg/l	11.4	0.5	96	2.6	0.3	88	8.9	0.4	96
Sludge										
kg/m^3 wastewater			1.13			0.62			0.74	
dry solids %			3.2			4.2			4.1	
OPERATIONAL DATA										
Flowrate		41 m^3/d, steady			147 m^3/d, steady			450 m^3/d, steady		
Dosing to flow or pH										
Flashmixer detention					nil			12 minutes		
Flocculator detention								40 minutes		
Settling tank retention					1.1 h			1.1 h		
Settling tank upward flow rate		m/h			1.6 m/h			2.7 m/h		
Sludge recirculation					nil			nil		
Source of results										
Periods of experimentation		No liming pH 10 pH 10.5 pH 11 pH 11.5			No liming pH 10 pH 10.5 pH 11 pH 11.5			No liming pH 10 pH 10.5 pH 11 pH 11.5		

LIMING TO 10·5 – DAVYHULME PILOT PLANT







DAVYHULME PILOT PLANT: REMOVAL OF HEAVY METALS IN PRIMARY SETTLEMENT APPENDIX A7

Metal	Without liming			With liming		
	Wastewater (mg/l)	Effluent (mg/l)	% Removal	Wastewater (mg/l)	Effluent (mg/l)	% Removal
Iron	6.3	3.4	46	6.2	1.5	76
Copper	0.61	0.38	38	0.42	0.17	60
Chromium	0.35	0.25	29	0.32	0.14	56
Lead	0.09	0.06	33	0.15	0.07	53
Mercury	0.028	0.022	21	0.028	0.014	50
Nickel	0.07	0.06	14	0.09	0.08	11
Zinc	0.74	0.47	36	0.66	0.26	60

Figures are average values.

Cadmium was generally under 0.01 mg/l in wastewaters and effluents, but on one occasion when 0.03 mg/l was present in the wastewater feed to unlined settlement, the effluent contained 0.01 mg/l.

CLIFF QUAY WASTEWATER TREATMENT WORKS IPSWICH: EVALUATION OF A POLYELECTROLYTE COAGULANT

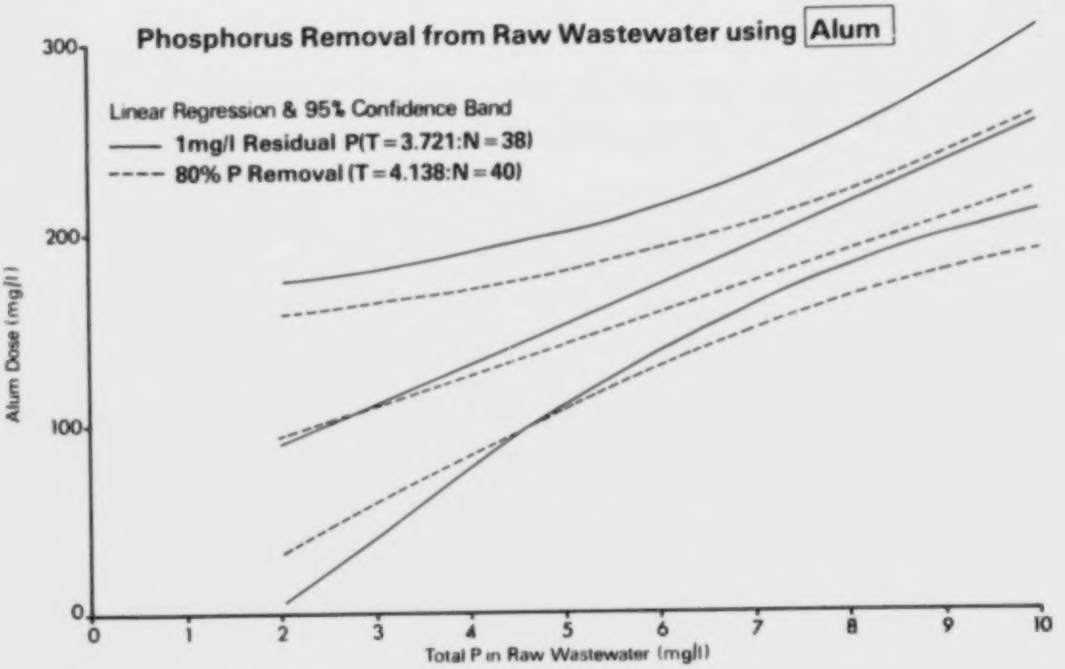
APPENDIX A8

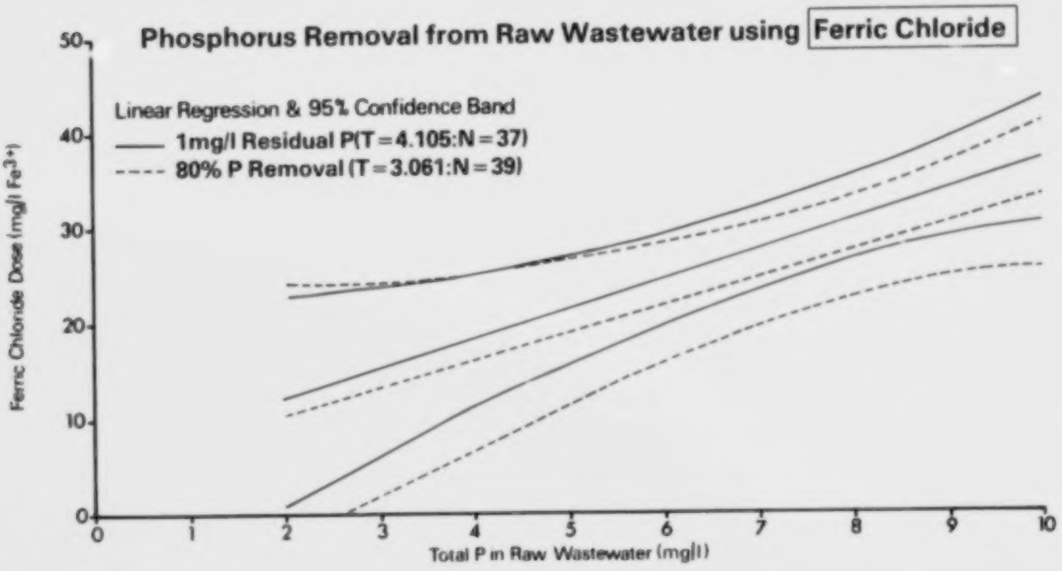
Parameter (CA = chemically-aided)		Dose of ZETAG 92* in chemically-aided stream (mg/l) 0.25	0.5	1	2	3	4
pH							
Raw wastewater		7.4	7.4	7.5	7.4	7.3	
Control effluent		7.3	7.4	7.5	7.4	7.5	
CA effluent		7.4	7.4	7.5	7.4	7.5	
SS							
Raw wastewater	mg/l	413	371	476	395	593	281
Control effluent	mg/l	217	176	163	191	176	147
removal %		47	52	66	52	73	48
CA effluent	mg/l	150	124	114	118	92	67
removal %		64	67	76	70	84	76
BOD$_5$							
Raw wastewater	mg/l	337	277	342	330	468	210
Control effluent	mg/l	270	210	211	203	242	173
removal %		19	32	38	38	48	18
CA effluent	mg/l	228	170	148	154	124	117
removal %		32	39	57	53	73	44
COD							
Raw wastewater	mg/l	770	617	913	661	810	474
Control effluent	mg/l	521	435	438	412	404	370
removal %		32	30	52	38	50	22
CA effluent	mg/l	412	355	340	312	268	241
removal %		46	42	63	53	67	49
TOTAL PHOSPHATE							
Raw wastewater	mg/l	10	9.3	9.6	9.3	7.2	5.8
Control effluent	mg/l	11	9.3	8.6	9.4	7.3	6.8
CA effluent	mg/l	10	8.6	7.4	9.2	6.6	5.8
SLUDGE							
Total solids (%)							
From control treatment		6.9	5.9	5.9	6.2	6.2	7.4
From CA treatment		6.2	5.1	5.7	6.5	6.4	4.7
CST (secs)							
From control treatment		154	145	199	198	115	128
From CA treatment		132	93	160	138	76	42

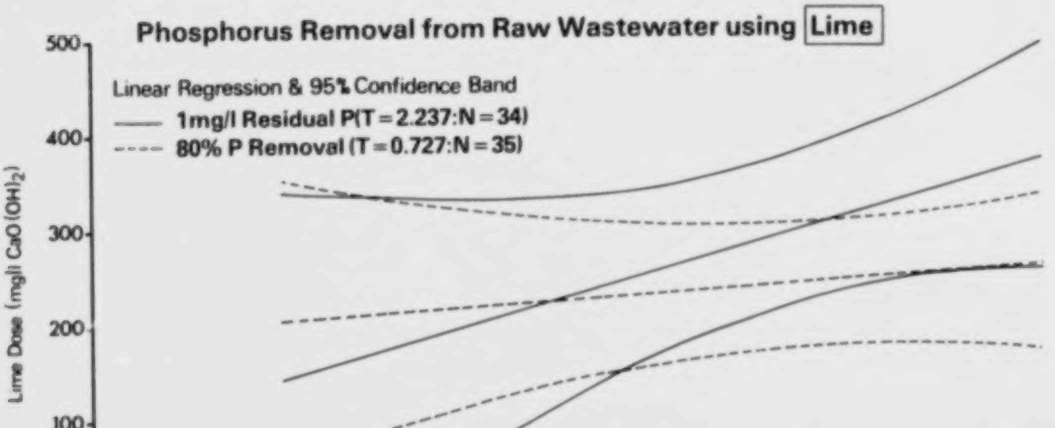
* Supplied by Allied Colloids Ltd. (Bradford)

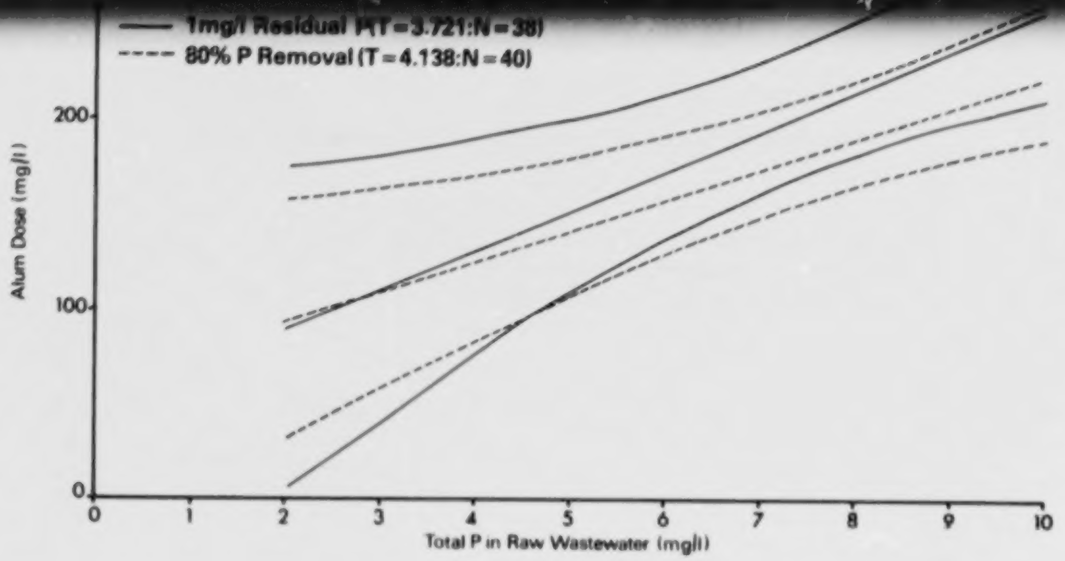
Appendix A9

CANADIAN JAR-TESTING WORK USING CHEMICALS ON RAW WASTEWATER

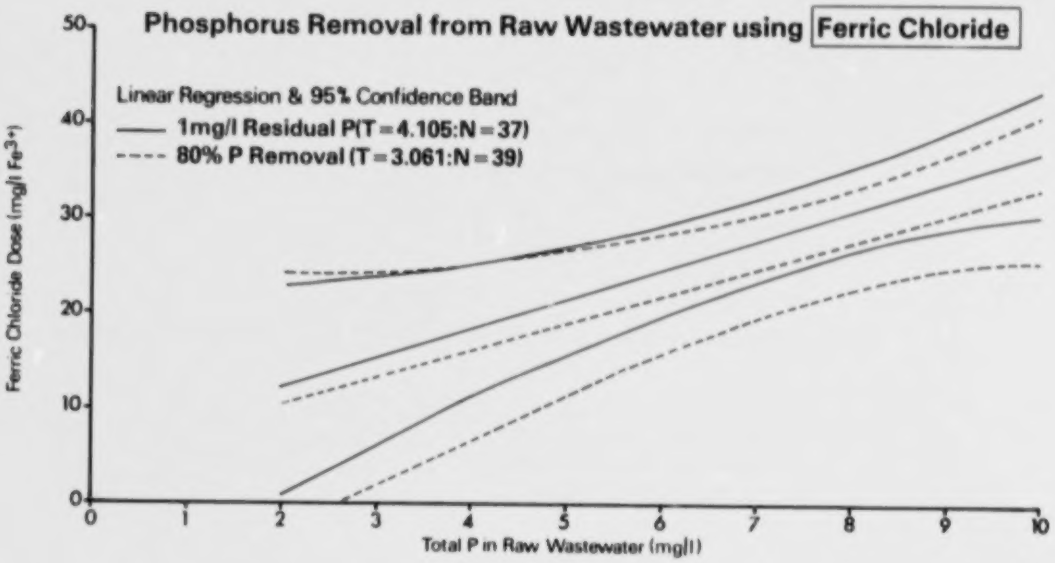

Phosphorus Removal from Raw Wastewater using Alum


Phosphorus Removal from Raw Wastewater using Ferric Chloride

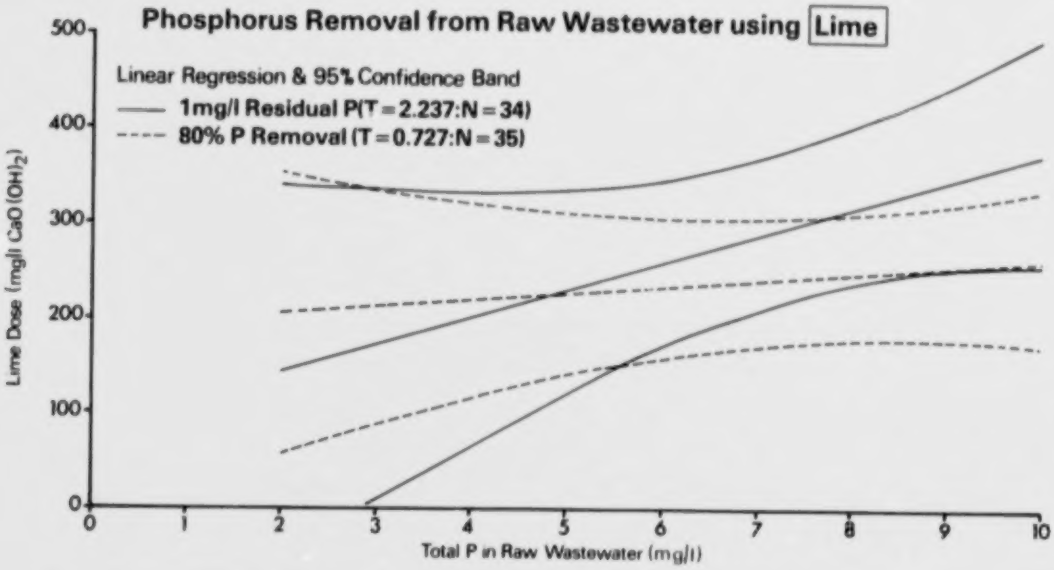

Phosphorus Removal from Raw Wastewater using Lime



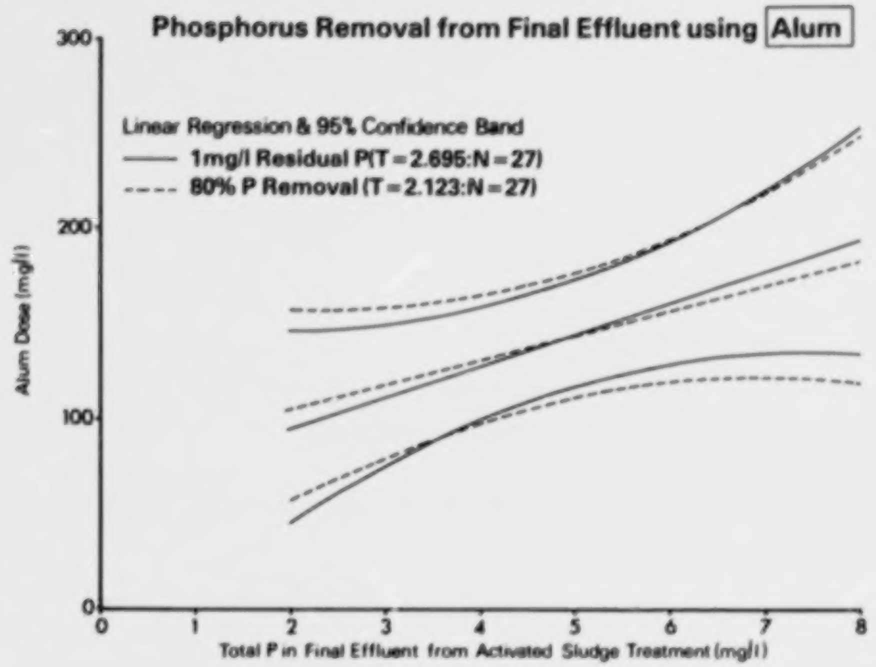
Phosphorus Removal from Raw Wastewater using **Ferric Chloride**

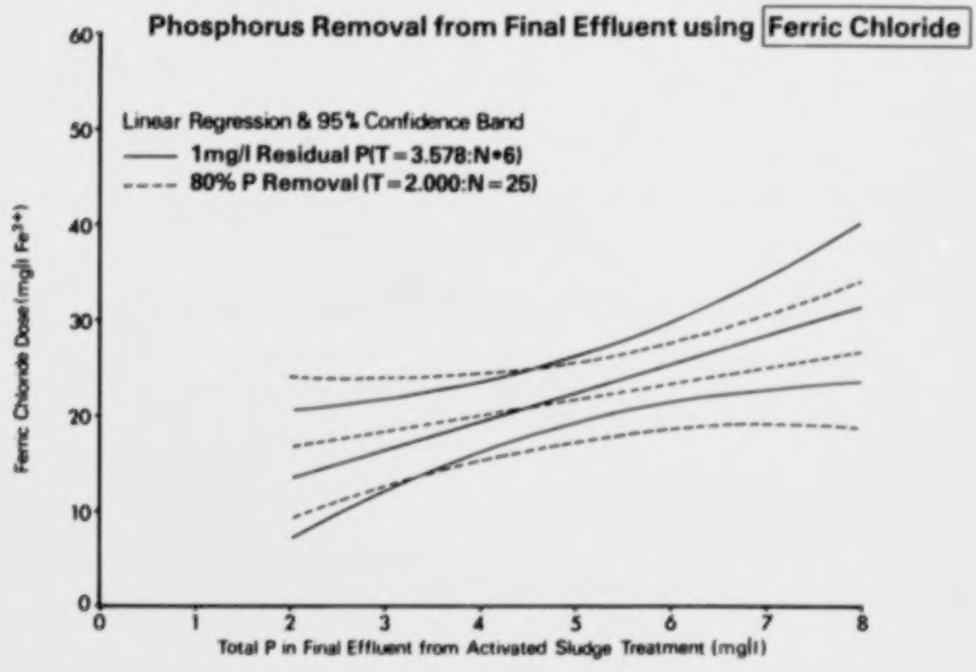


Phosphorus Removal from Raw Wastewater using **Lime**



CANADIAN JAR-TESTING WORK USING CHEMICALS ON SECONDARY EFFLUENT


Phosphorus Removal from Final Effluent using **Alum**


Phosphorus Removal from Final Effluent using **Ferric Chloride**

CANADIAN WORK ON PREDICTING CHEMICAL DOSES

Sheet 1

Works No.	Works type and throughput (m^3/d) at dwf	Coagulant and predicted dose (mg/l)	Actual dose (mg/l)	Applied at	Effluent quality (mg/l) and removals %				Effluent quality	Remarks
					total P		BOD		SS (mg/l)	
1	Primary settlement (100,000)	Alum (100)	100	inlet	0.5	93	34	72	20	alum + 0.5 polymer A-23) Windsor works
			90	inlet	1.0	87	42	61	30	alum + 0.5 polymer A-23)
2	Primary settlement (35,000)	Ferric chloride (Fe^{3+}) (15)	15	inlet	1.2	78	39	61	33	)
			15	inlet	1.3	77	34	68	26	ferric + 0.5 polymer A-23) Sarnia works
			20	inlet	0.7	85	37	62	28	)
			20	inlet	0.8	88	33	67	17	ferric + 0.5 polymer A-23)
3	Activated sludge (13,000)	Alum (200)	200	inlet	0.5	96	7	98	15	Sludge recycling at all doses. Barrie works
			150	inlet	1.2	88	5	99	15	
			100	inlet	1.8	80	8	98	12	
			100	aeration tanks	1.7	98	16	97	19	
			75	aeration tanks	2.6	92	23	96	32	
4	Activated sludge (18,000)	Alum (150)	150	inlet	1.2	88	25	81	11	Little River works
5	Activated sludge (18,000)	Alum (125)	125	inlet	1.6	84	22	88	40	pH unaffected) wastewater from low alkalinity
			125	aeration tanks	1.7	78	37	82	56	pH unaffected) raw water. North Bay works.
			175	aeration tanks	0.5	93	36	81	23	pH depressed to 3, at times)
6	Activated sludge (3500)	Alum (175)	131	aeration tanks	1.3	88	22	92	24	Sludge recycling. Orangeville works.
7	Activated sludge (27,000)	Ferric chloride (Fe^{3+}) (10)	10	inlet	0.8	88	15	87	6	Peterborough works.
8	Activated sludge (18,000)	Ferrous sulphate ($Fe^{2}+$) (40)	20	inlet	3.0	83	21	88	13	Sludge recycling. Waste pickle liquor as coagulant. Chatham works.
9	Activated sludge (9,000)	Lime (–)	200	inlet	2.0	80	9	96	7	Newmarket/East Gwillimbury works.
10	Activated sludge (900)	Lime 70	130	inlet	3.1	45	6	91	13	Dose of 225 mg/l could be needed for required P removal, as waste water had 300 mg/l alkalinity, 950 mg/l total hardness (as $CaCO_3$). Hagersville works.

CANADIAN WORK ON PREDICTING CHEMICAL DOSES REQUIRED (contd.)

Sheet 2

11	Activated sludge (18,000)	Lime (150)	125	inlet	1.8	80	31	73	6	Little River Works, Windsor
12	Contact stab'in (2,200)	Alum (125)	125	contact zone	0.3	94	3	90	7	) High quality effluents consistently maintained
		ferric chloride (Fe^{3}+) (15)	15	contact zone	0.9	88	9	94	14	)
13	Extended aer'n (220)	Alum (–)	230	inlet	1.5	91	14	91	55	) Poor quality effluents. Better results thought possible had dosing
		ferrous sulphate)	13	inlet	4.1	68	16	89	40	) been at exit from aeration tanks.
		(Fe^{2}+) (–)	15	inlet	2.6	86	12	94	32	)
14	Oxidation ditch (3,500)	Alum (125)	125	inlet	1.0	80	17	63	37	) No solids deposition in ditch. Port Elgin Works.
		ferric chloride (Fe^{3}+) (15)	15	inlet	0.8	83	6	91	11	)

CANADIAN COMPARISONS OF PREDICTED AND REAL TANK PERFORMANCES APPENDIX A12

Retention time in real tank (minutes)		overflow rate (m^3/m^2d)	Suspended solids		
			In feed (mg/l)	Removals (%)	
Theoretical	Actual			Predicted	Actual
BURLINGTON (CIRCULAR TANK)					
Without coagulant					
110	42	30	Average	54	43
66	36	50	242	44	41
33	24	100		33	34
With ferric chloride					
100	42	30	325	83	80
66	36	50	254	78	78
33	24	100	255	68	70
With ferric chloride and polymer					
110	42	30	280	89	90
66	36	50	409	88	89
33	24	100	237	83	84
SARNIA (RECTANGULAR TANK)					
Without coaguiant					
110	80	37	Average	57	52
69	51	60	169	47	46
37	26	110		34	36
With ferric chloride					
110	80	37	Average	86	85
69	51	60	179	78	82
37	26	110		72	71
With ferric chloride and polymer					
110	80	37	Average	93	94
69	51	60	167	92	92
37	26	110		87	86
WINDSOR (CIRCULAR TANK)					
Without coagulant					
200	60	25	Average	48	48
100	33	50	154	38	39
67	27	75		35	36
With ferric chloride					
200	60	25	Average	87	84
100	33	50	191	78	77
67	27	75		61	60
With ferric chloride and polymer					
200	60	25	Average	88	91
100	33	50	202	89	87
67	27	75		80	80

Appendix A13

Recarbonation experience at Coleshill

1. When the first-stage recarbonation unit was available, plant experiments comprised lime dosing to constant pH, flocculation and 1 hour settlement. This was followed by recarbonation to pH 9.25.

2. Problems due to scale formation in pipes and in the feed pump appeared rapidly and the flow through the unit quickly decreased. In the extreme case, with lime dosing to pH 11.3, the flow rate dropped from 1360m^3/d to under 450m^3/d within 96 hours. However, with regular descaling, operation was possible for lime treatment at pH 9.5, 10.0, 10.5 and 11.0 but the rapidity of scaling when (treating) above pH 11.0 inhibited further work. Single-stage recarbonation to pH 7.0 was also carried out but scaling problems were still severe.

3. The prime cause of scaling was the need to recirculate recarbonated effluent to maintain sufficient influent to the unit's constant-delivery pump. When the unit was operated without carbon dioxide injection, the running time increased to one month.

4. Modifications were made to overcome the problem of recarbonated effluent passing through the pump and its delivery line. These allowed for recirculating effluent drawn from upstream of the unit. The unit now has a gravity-fed influent tank, the pump suction being from its base. The excess flow delivered by the pump over the incoming flow is returned to the influent tank via a ball valve. The carbon dioxide injection point was subsequently moved to the inner dispersion bell from its previous position in the pump delivery line, again to reduce pipework scaling.

5. After these modifications were completed, 18 weeks relatively uninterrupted operation were achieved before de-scaling was required.

6. Subsequent commissioning of the carbonate settlement tank (nominal retention 2.5 h) made two-stage recarbonation possible.

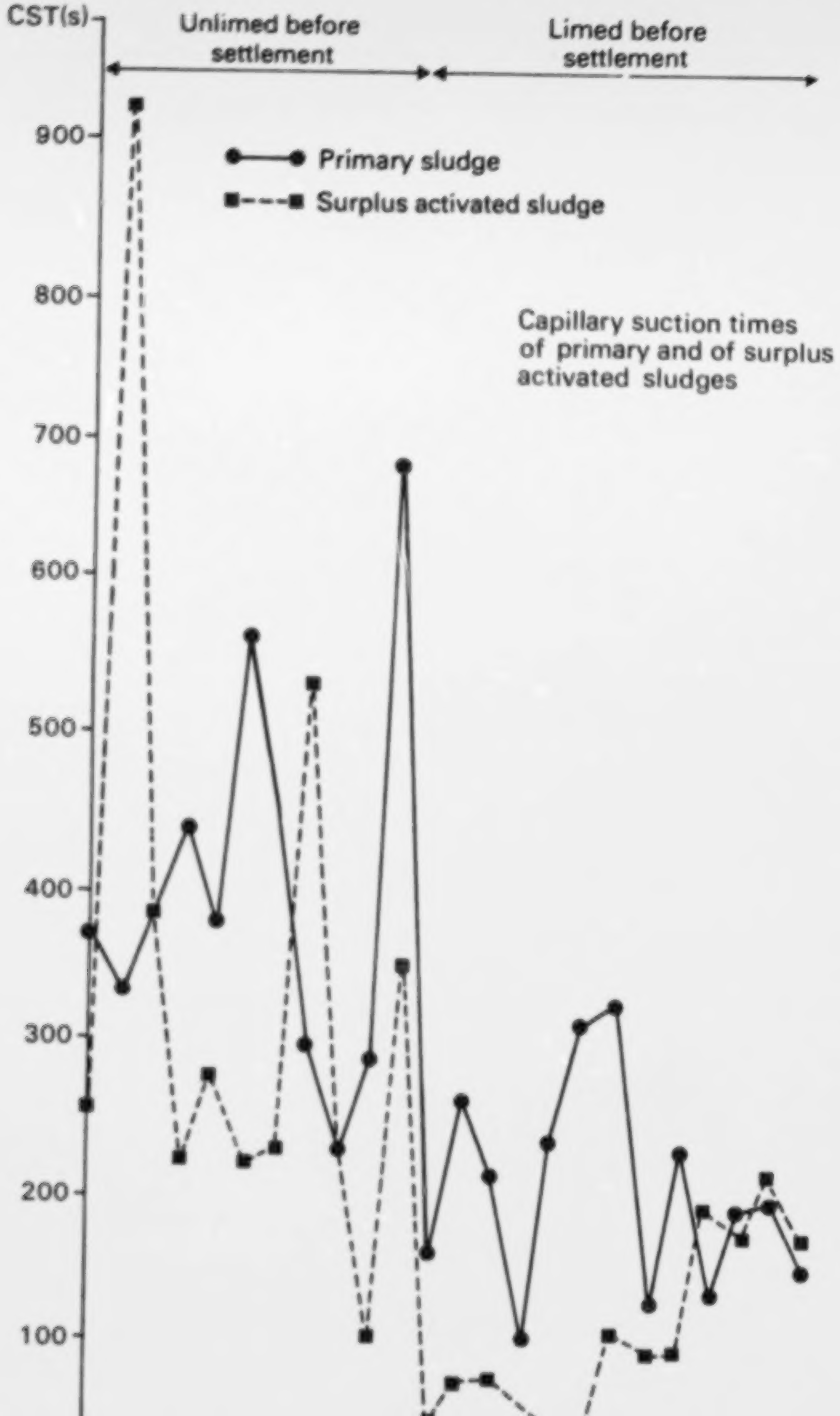
7. The only major operationsl problems occurring thereafter were blocking of the interconnecting pipe between the first-stage unit and the carbonate settlement tank, and difficulty in handling the dense carbonate sludge, which at times contained 50% dry solids.

SUMMARISED DATA ON SUBSTITUTE CHEMICALS

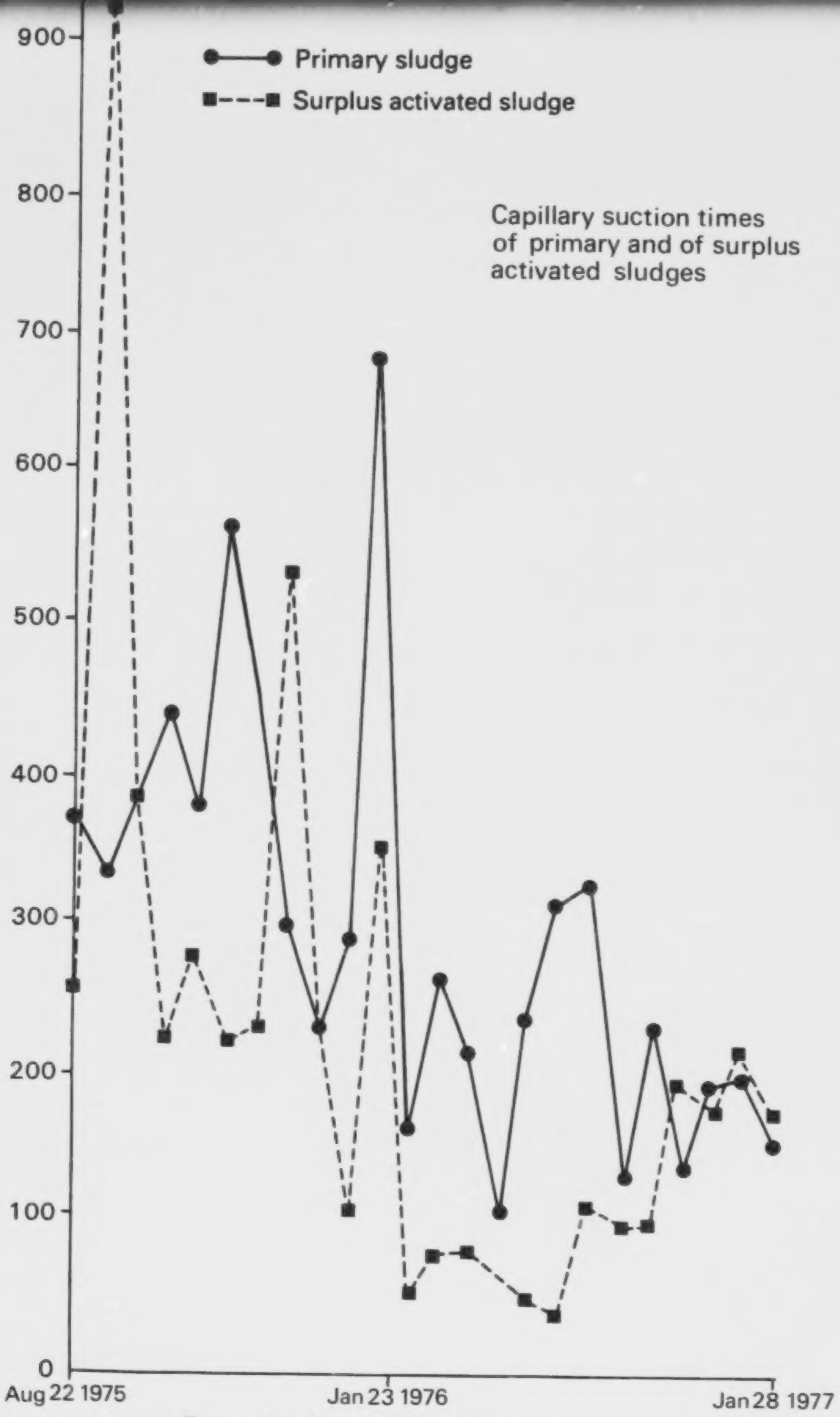
APPENDIX A14

	Name; significant items in composition (mg/l except where noted)	Optimum pH for settlement; dose needed to give effluent with 1 mg/l or less total phosphorus	Quantity of wastewater that might be treated to the required standard using quantities of substitute chemical shown to be available by survey – tcmd (mgd).
1	PICKLE LIQUORS Fe 30000-90000, Al 4-40 Cr 0.5–40, Cu 5–10 Mn 200–3500, Ni 20–25, Pb 4–10, Zn 9–13; H_2SO_4 5–15%	7–10 20–30 mg/l as Fe	791 (174) at dosage 20 mg/l. Pickle liquors produced from MILL SCALE could treat 4546 (1000) at the same dosage (see serial 8)
2	SPENT MINE ACIDS Fe 20000–25000, Al 3000–6000, Cr 100–400, Mn 100–200; a little Cu, Ni, Pb, Zn; H_2SO_4 20–25%	7–10 20–30 mg/l as Fe	1364 (300)
3	CARBIDE LIME Ca 52%, SiO 5%, Fe 0.3%, Al 0.2%, Mg 0.1%	over 8.5. 5000 mg/l or 350 as available $Ca(OH)_2$	136 (30)
4	STACK PRECIPITATOR DUSTS Ca 25–30%, Fe 1%, P 1–2%, Mg 1%, K 4–14%	over 8.5. 2000 mg/l, or 1100 as $Ca(OH)_2$	114 (25)
5	BAG-HOUSE DUSTS Composition varied depending on original production process	over 8.5 for lime dusts. 200–600 mg/l	18 (4)
6	RED MUDS Al 8%, Ca 3.5%, Fe 10%, Si 8%.	under 7 or over 9. 5000 mg/l red mud slurry.	4546 (1000)
7	DROSS Al 40%, Al_2O_3 30%, Na C1 30%	–	227 (50)
8	MILL SCALE Fe_3O_4 99%, Mn 0.5%, CO.2%, SO_2 0.03%, PO.03%	–	not directly useful – see serial 1.

Appendix A15

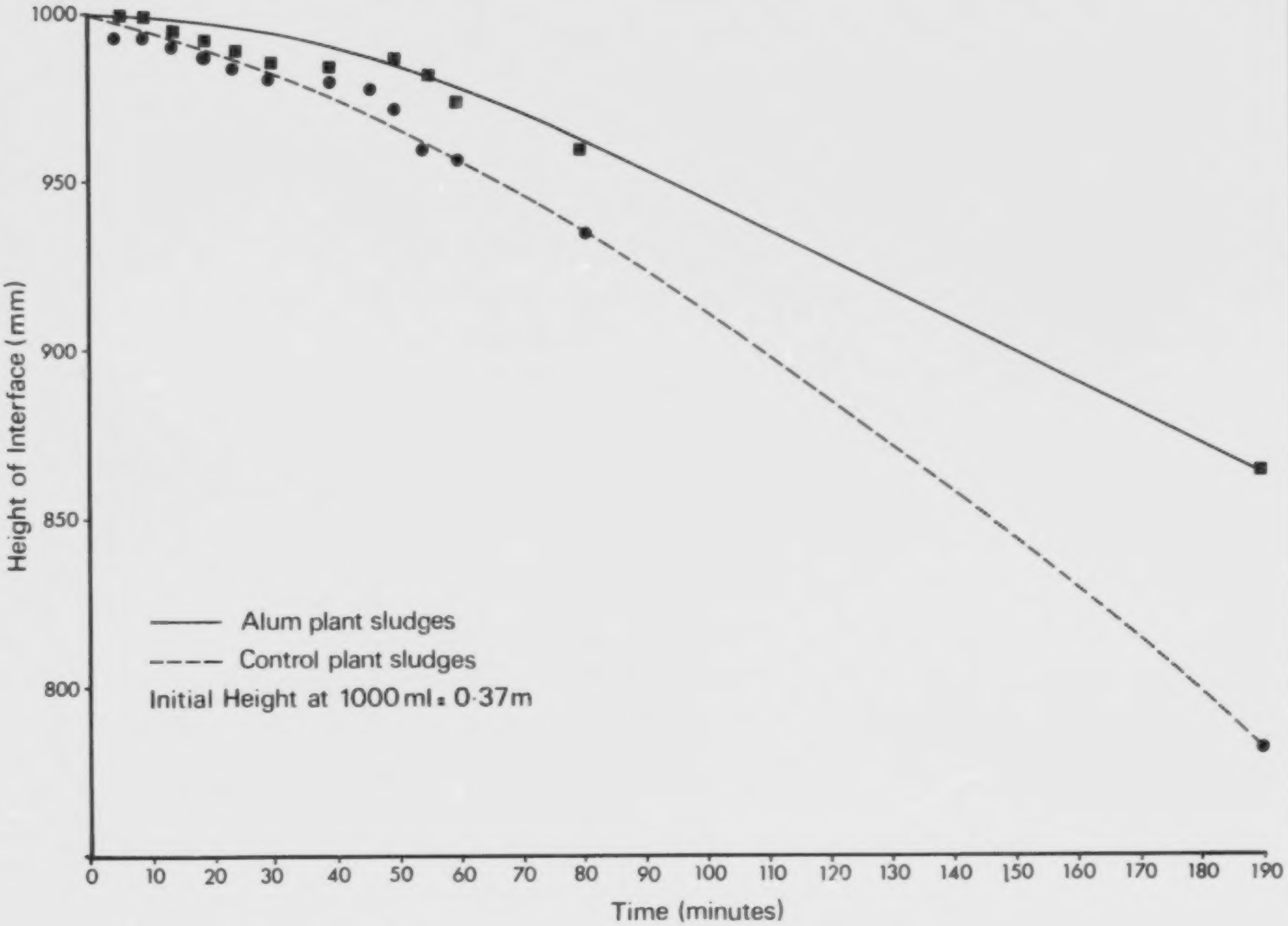


Capillary suction times of primary and of surplus activated sludges

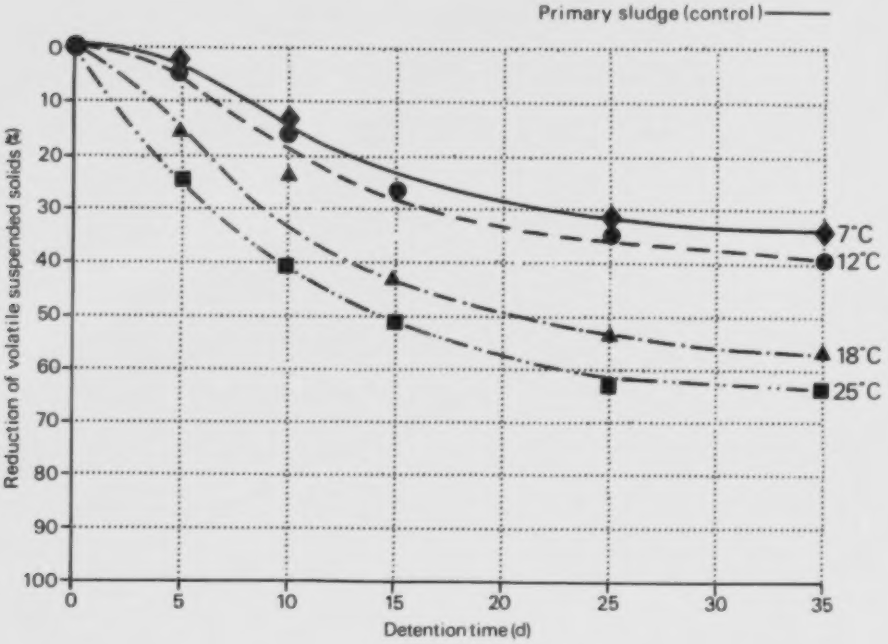


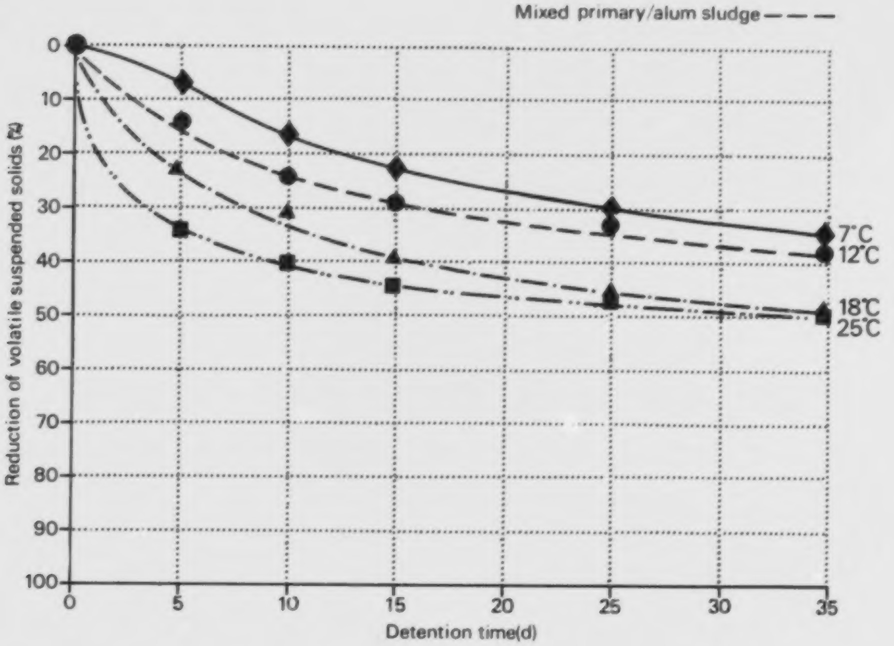
Davyhulme Pilot Plant

Settlement rates of mixed primary and surplus activated sludges from control and alum-dosed activated sludge plants, Guelph works, Ontario.



Aerobic treatment of primary (control) and mixed primary/alum sludges in Norway





FILTER PERFORMANCE IN USA AND UK

APPENDIX A18/1

Location	No. of media layers	Loading m^3/m^2h)	Filter Influent (mg/l)					Filter Effluent (mg/l)				
			SS	BOD_5	COD	TOC	TotP	SS	BOD_5	COD	TOC	TotP
South Tahoe California	3	12*	15	9	23		0.65	0	5	15		0.05
Blue Plains Washington		7	20	25	55	22	0.30	5	21	48	20	0.20
Coleshill England	2	7	31	77	168	51	0.30	7	64	140	38	0.26

* Two filters used in series.

CARBON COLUMN PERFORMANCE AT POMONA, CALIFORNIA

APPENDIX A18/2

Parameters	Adsorption Cycles			Overall averages
	1	2	3	
Total COD				
Raw Sewage	331	295	315	321
Carbon Column Influent, mg/l	98.4	86.2	93.2	95.8
Carbon Column Effluent, mg/l	23.6	10.0	11.5	19.3
Carbon Column Removal, %	76.0	88.4	88.3	79.9
Dissolved COD				
Raw Sewage	50.4	45.6	50.8	49.4
Carbon Column Influent, mg/l	48.0	48.4	52.1	48.6
Carbon Column Effluent, mg/l	16.1	7.2	9.4	13.5
Carbon Column Removal, %	66.5	85.1	81.9	72.2
Colour				
Carbon Column Influent, colour units	19.2	20.4	21.6	20.0
Carbon Column Effluent, colour units	9.8	6.0	4.7	7.8
Carbon Column Removal, %	49.0	70.6	78.2	61.0
Suspended Solids				
Raw Sewage	205	180	198	199
Carbon Column Influent, mg/l	30.9	22.8	24.5	28.3
Carbon Column Effluent, mg/l	8.3	4.0	3.8	6.7
Carbon Column Removal, %	73.1	82.5	84.5	76.3
Turbidity				
Carbon Column Influent, JTU	24.4	19.9	20.6	22.9
Carbon Column Effluent, JTU	7.7	3.8	3.6	6.3
Carbon Column Removal, %	68.4	80.9	82.5	72.5

CARBON COLUMN PERFORMANCE AT BLUE PLAIN, WASHINGTON

APPENDIX A18/3

Parameter	Raw sewage mg/l	Carbon column influent mg/l	Final column effluent mg/l
TOC	100	20	8
COD	295	48	16
BOD_5	134	21	6
SS	158	5	4
P	7.9	0.2	0.1

CARBON COLUMN PERFORMANCE AT ROSEMOUNT, MINNESOTA

APPENDIX A18/4

Parameter	Raw sewage mg/l	Carbon column effluent mg/l	Final column influent mg/l
TOC	105	21	12
COD	567	73	38
BOD_5	229	33	25
SS	264	11.5	8.5

CARBON COLUMN PERFORMANCE AT ROCKY RIVER, OHIO

APPENDIX A18/5

Parameter	Raw sewage mg/l	Carbon column influent mg/l	Final column effluent mg/l
COD	219	91	50
BOD_5	118	39	18
SS	149	42	21

MEASURES TAKEN TO OVERCOME SULPHIDE PRODUCTION AT POMONA, CALIFORNIA

Control Method	Average total sulphide mg/l
Backwash/Surface wash;	2.9
Backwash/Surface wash; intermittend O_2 to 4 mg/l	1.9
Backwash/Surface wash; continuous O_2 to 2-6 mg/l air scour	1.9
Backwash/Surface wash; $C1_2$ to 20 mg/l air scour	1.7
Backwash/Surface wash; $C1_2$ to 40 mg/l air scour	1.1
Backwash/Surface wash; NO_3 to 2.9 mg/l N air scour	0.3
Backwash/Surface wash; NO_3 to 4.5 mg/l N air scour	0.1
Backwash/Surface wash; NO_3 to 5.4 mg/l N	0.0

MEAN RESULTS OF PERFORMANCE OF BENCH-SCALE PCT PILOT PLANT AT STEVENAGE, UK

Sample	Organic carbon mg/l	COD mg/l	BOD_5 mg/l
Raw sewage	333	1028	546
Settled lime-treated sewage	124	–	–
Recarbonated settled lime-treated sewage	107	275	–
Liquor leaving			
1st carbon contactor	76	220	–
2nd carbon contactor	56	166	–
3rd carbon contactor	52	150	–
4th carbon contactor	40	110	50
% Reduction by activated carbon (All columns)	63	60	–

GROSS PARAMETERS OF WATER QUALITY OF SAMPLES OF PCT PLANT EFFLUENT FROM COLESHILL AND A WRC SMALL-SCALE ACTIVATED -SLUDGE PLANT OPERATED IN PARALLEL, UK

APPENDIX A18/8

	Concentration (mg/l)	
	PCT plant final effluent	AS plant final effluent
BOD_5	7	5
COD	26	66
TOC	5.1	13.3

PERFORMANCE OF SMALL SCALE CARBON COLUMNS AT COLESHILL, UK AFTER 30 DAYS OPERATION

APPENDIX A18/9

Parameter	Carbon column influent mg/l	Carbon column effluent mg/l
TOC	29	26
COD	109	86
BOD_5	55	42
SS	14	12

Results from G.C.M.S. Analysis of both activated carbon and activated sludge process effluents at Coleshill

1. Samples were taken of the effluents from the PCT stream (pilot scale) carbon columns) and a small scale activated sludge plant, each treating domestic sewage. These were taken on two occasions, corresponding to the fresh and near-exhausted stages of the activated carbon. The accompanying table gives a composite list of compounds identified in each process effluent.

2. The extraction methods used were:
   head space analysis (Grob-strip) for volatile compounds, liquid/liquid solvent extraction with hexane, diethyl ether and butanol, solvent extraction and methylation.

3. All extracts were subsequently analysed using gas chromatography-mass spectroscopy.

4. The results given are qualitative and may not be representative of the majority of carbonaceous organic matter present.

General Groups and Specific Compounds Tentatively Identified

A. Common to PCT and ACT Effluents

n-alkanes
iso-alkanes
phenyl-alkanes
branched bromoalkanes
dicylchlohexylalkanes
saturated and unsaturated aliphatic acids
aliphatic alcohols (straight and branched chain)
phthalate esters

tributyl phosphate
xylene
toluene
ethylbenzene
propylbenzene
chlorobenzene
dichlorobenzene
butyl benzylphalate
styrene
2-methylthiobenzothiazole
p-cresol
dimethyl phenol
tert-butyl methylphenol
p-α-cumyl phenol
dichloroxylenol
acetyl cedrene
fluoranthrene
pyrene

B. Identified in ASP Effluents but not in PCT Effluent

squalene
acetone
ethyl phenyl acetate
trimethyl benzene
dimethyl tert-butyl phenol
2-chloro-2-methoxydi-t-butyl ether
2-methylbenzothiazole

C. Identified in PCT Effluent but not in ASP Effluent

sulphur
dimethyl disulphide
methyl ethyl sulphide
dimethyl trisulphide
methane thiol
cyclopentanol
phenol
methyl quinolene
anisole

KE CITY POWDERED ACTIVATED CARBON PLANT (UTAH, USA)

G PERIOD I: AVERAGE OPERATING CONDITIONS AND TREATMENT RESULTS JULY 13 TO SEPTEMBER 30, 1972

Operating Conditions

ydrated Lime:	@ 460 mg/l (10.8 to 11.2 treatment pH)	
H_2SO_4:	@ 2030 lb/MG = 244 mg/l	
aulic loading:	Chemical contactor	2.3 (1.2^a) m^3/m^{2}h (0.94 (0.49^a) gpm /ft^2)
	Carbon Contactor	1.6 (0.78^a) m^3/m^{2}h (0.66 (0.32^a) gpm /ft^2)
	GM Filter	5.1 m^3/m^{2}h (2.1 gpm /ft^2)
cting mode:	Single stage	
:	First contactor	280 mg/l
	Second contactor	300 mg/l

ment results	Raw wastewater	Chemical effluent	Neutralized Chemical effluent	Plant effluent
U	33	4	4	3
lids, mg/l	87	14	10	5
nce	–	–	–	97
P	4.50	0.29	–	0.20
P, mg/l P	3.16	0.14	0.15	0.11
mg/l P	2.82	0.10	0.06	0.11
4, mg/l P	2.25	0.04	0.05	0.08
	136	–	55	14
	30	–	35	11
	7.5	10.2	7.1	7.2
alkalinity^b	293	116	65	58
in alkalinity^b	–	66	–	–
s^b	417	239	317	328
ness^b	255	197	284	250

8/9 only

$CaCO_3$

SALT LAKE CITY POWDERED ACTIVATED CARBON PLANT (UTAH, USA)

OPERATING PERIOD I: AVERAGE OPERATING CONDITIONS AND TREATMENT RESULTS JULY 13 TO SEPTEMBER 30, 1972

	Operating Conditions	
Chemicals: Hydrated Lime:	@ 460 mg/l (10.8 to 11.2 treatment pH)	
H_2SO_4:	@ 2030 lb/MG = 244 mg/l	
Average Hydraulic loading:	Chemical contactor	2.3 (1.2^a) m^3/m^2h (0.94 (0.49^a) gpm /ft^2)
	Carbon Contactor	1.6 (0.78^a) m^3/m^2h (0.66 (0.32^a) gpm /ft^2)
	GM Filter	5.1 m^3/m^2h (2.1 gpm /ft^2)
Carbon contacting mode:	Single stage	
Carbon dosage:	First contactor	280 mg/l
	Second contactor	300 mg/l

Average process treatment results	Raw wastewater	Chemical effluent	Neutralized Chemical effluent	Pl eff
Turbidity, JTU	33	4	4	3
Suspended solids, mg/l	87	14	10	5
% Transmittance	–	–	–	97
Total P, mg/l P	4.50	0.29	–	0.
Soluble total P, mg/l P	3.16	0.14	0.15	0.
Total dPO4, mg/l P	2.82	0.10	0.06	0.
Soluble, dPO4, mg/l P	2.25	0.04	0.05	0.
COD, mg/l	136	–	55	14
SCOD, mg/l	30	–	35	11
pH	7.5	10.2	7.1	7.
Methyl orange alkalinity^b	293	116	65	58
Phenolphthalein alkalinity^b	–	66	–	–
Total hardness^b	417	239	317	328
Calcium hardness^b	755	197	294	250

a – 7/29 to 8/9 only

b – mg/l as $CaCO_3$

SALT LAKE CITY POWDERED ACTIVATED CARBON PLANT (UTAH, USA)

OPERATING PERIOD II; AVERAGE OPERATING CONDITIONS AND TREATMENT RESULTS JANUARY 6 TO FEBRUARY 20, 1973

		Operating Conditions
Chemicals:	Hydrated Lime:	@ 48 mg/l (10.8 to 11.2 Operating pH)
	H_2SO_4	@ 2080 lb/MG = 250 mg/l
Average hydraulic loading:	Chemical contactor	$2.1 m^3/m^2 h$ (0.84 gpm/ft^2)
(constant flow)	Carbon contactor	$1.4 m^3/m^2 h$ (0.56 gpm/ft^2)
	GM filter	$7.3 m^3/m^2 h$ (3.0 gpm/ft^2)
Carbon contacting mode:	Single stage	
Carbon dosage:	First contactor	183 mg/l
	Second contactor	134 mg/l

Average process treatment results	Raw wastewater	Chemical effluent	Neutralized chemical effluent	Plant effluent
Turbidity, JTU	47	7	3	4
Suspended solids, mg/l	99	27	9	19
% Transmittance	–	–	–	90
Total P, mg/l P	4.88	0.26	–	0.21
Soluble total P, mg/l P	3.62	0.13	0.21	0.13
Total σ PO_4, mg/l P	2.54	0.09	0.13	0.09
Soluble σ PO_4, mg/l P	2.07	0.06	0.08	0.06
COD, mg/l	127	–	46	41
SCOD, mg/l	41	–	41	10
BOD_5 mg/l	84	–	25	5
pH, units	7.4	10.3	8.0	8.0
Methyl orange alkalinity,[a]	342	142	64	49
Phenolphthalein alkalinity,[a]	–	86	–	–
Total hardness,[a]	484	251	387	360
Calcium hardness,[a]	272	211	289	298

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[a] mg/l as $CaCO_3$

SALT LAKE CITY POWDERED ACTIVATED CARBON PLANT (UTAH, USA)

OPERATING PERIOD III: AVERAGE OPERATING CONDITIONS TREATMENT RESULTS MARCH 28 TO JUNE 7, 1973

	Operating Conditions	
Chemicals:	Alum @ 14.0 mg/l – Al	
Average hydraulic loading:	Chemical contactor	0.93 m^3/m^2h (0.38 gpm/ft^2)
	First stage carbon	1.2 m^3/m^2h (0.51 gpm/ft^2)
	Second stage carbon	1.1 m^3/m^2h (0.44 gpm/ft^2)
	GM Filter	4.9 m^3/m^2h (2.0 gpm/ft^2)
	Peak to minimum	2:1 and 7:1
Carbon contacting mode:	Two-stage counter-current	
Carbon dosage:		294 mg/l and 104 mg/l

Average process treatment results	Raw wastewater	Chemical effluent	Plant effluent
Turbidity, JTU	53	11	2
Suspended, solids, mg/l	174	29	9
% Transmittance	–	–	97
Total P, mg/l P	5.03	0.67	0.2
Soluble total P, mg/l P	3.87	0.14	0.1
Total dPO_4, mg/l P	2.91	0.28	0.1
Soluble dPO_4, mg/l P	2.52	0.08	0.07
COD, mg/l	143	41	6/11[a]
SCOD, mg/l	38	23	2.0/5.0[a]
BOD_5, mg/l	112	26	3/8[a]
pH, units	7.1	7.3	7.5

a – 294 mg/l of PAC/104 mg/l of PAC

SALT LAKE CITY POWDERED ACTIVATED CARBON PLANT (UTAH, USA)

OPERATING PERIOD IV: AVERAGE OPERATING CONDITIONS AND TREATMENT RESULTS JUNE 10 TO AUGUST 13, 1973

	Operating Conditions	
Chemical:	$FeCl_3$ @ 96 mg/l	
Average hydraulic loadings:	Chemical contactor	0.9[illegible]^3/m^{2}h (0.38 gpm/ft^2)
	First stage carbon	1.3m^3/m^{2}h (0.52 gpm/ft^2)
	Second stage carbon	1.1m^3/m^{2}h (0.46 gpm/ft^2)
	GM Filter	5.1m^3/m^{3}h (2.1 gpm/ft^2)
	Peak to minimum	2:1
Carbon contacting mode:	Two-stage counter-current	
Carbon dosage:		96 mg/l

Average process treatment results	Raw wastewater	Chemical effluent	Plant effluent
Turbidity	49	42	3
Suspended solids, mg/l	118	26	3
% Transmittance	–	–	99
Total P, mg/l	4.93	0.52	0.29
Soluble total P, mg/l	3.80	0.11	0.20
Total oPO_4, mg/l P	3.76	0.38	0.19
Soluble oPO_4, mg/l P	3.35	0.05	0.13
COD, mg/l	126	28	3
SCOD, mg/l	35	19	2
BOD_5, mg/l	97	7	3
pH, units	7.2	7.3	7.6

SALT LAKE CITY POWDERED ACTIVATED CARBON PLANT (UTAH, USA)

OPERATING PERIOD V: AVERAGE OPERATING CONDITIONS AND TREATMENT RESULTS AUGUST 14 TO SEPTEMBER 15, 1973

Operating Conditions

Chemicals: $FeCl_3$:	@ 62 mg/l	
Polymer:	@ 0.25 mg/l	
Average hydraulic loading:	Chemical contactor	$0.95\ m^3/m^2h$ ($0.39\ gpm/ft^2$)
	First stage carbon	$1.3\ m^3/m^2h$ ($0.52\ gpm/ft^2$)
	Second stage carbon	$1.1\ m^3/m^2h$)$0.45\ gpm/ft^2$)
	GM Filter	$6.7 m^3/m^2h$ ($2.7\ gpm/ft^2$)
	Peak to minimum	2:1
Carbon contacting mode:	Two-stage counter-current	
Carbon dosage:		98 mg/l

Average process treatment results	Raw wastewater	Chemical effluent	Plant effluent
Turbidity, JTU	43	35	2
Suspended solids, mgl/l	166	35	4
% Transmittance	–	–	99
Total, P, mg/l P	4.94	0,80	0.67
Soluble total P, mg/l P	3.67	0.24	0.61
Total dPO_4, mg/l P	4.31	0.51	0.63
Soluble dPO_4, mg/l P	3.76	0.10	0.59
COD, mg/l	133	28	3
SCOD, mg/l	30	16	3
BOD_5, mg/l	58	16	3
pH, units	7.2	7.2	7.3

SALT LAKE CITY POWDERED ACTIVITATED CARBON PLANT (UTAH, USA)

OPERATING PERIOD VI: AVERAGE OPERATING CONDITIONS AND TREATMENT RESULTS SEPTEMBER 28 TO NOVEMBER 8, 1973

Operating Conditions

Chemicals:	Alum:	@ 9.6 mg/l – Al	
	Polymer:	@ 0.25 mg/l	
Average hydraulic loading:		Chemical contactor	$1.2 m^3/m^2 h$ ($0.49 gpm/ft^2$)
		First stage carbon	$1.5 m^3/m^2 h$ ($0.63 gpm/ft^2$)
		Second stage carbon	$1.3 m^3/m^2 h$ ($0.55 gpm/ft^2$)
		GM Filter	$8.5 m^3/m^2 h$ ($3.5 gpm/ft^2$)
		Peak to minimum	2:1 and 3:1
Carbon contacting mode:		Two-stage counter-current	
Carbon dosage:			62 mg/l Fixed carbon

Average process treatment results	Raw wastewater	Chemical effluent	Plant effluent
Turbidity, JTU	59	8	8
Suspended solids, mg/l	263	26	8
% Transmittance	–	–	97
COD, mg/l	179	49	11
SCOD, mg/l	44	24	8
BOD_5, mg/l	187	37	6
pH, units	7.1	7.3	–

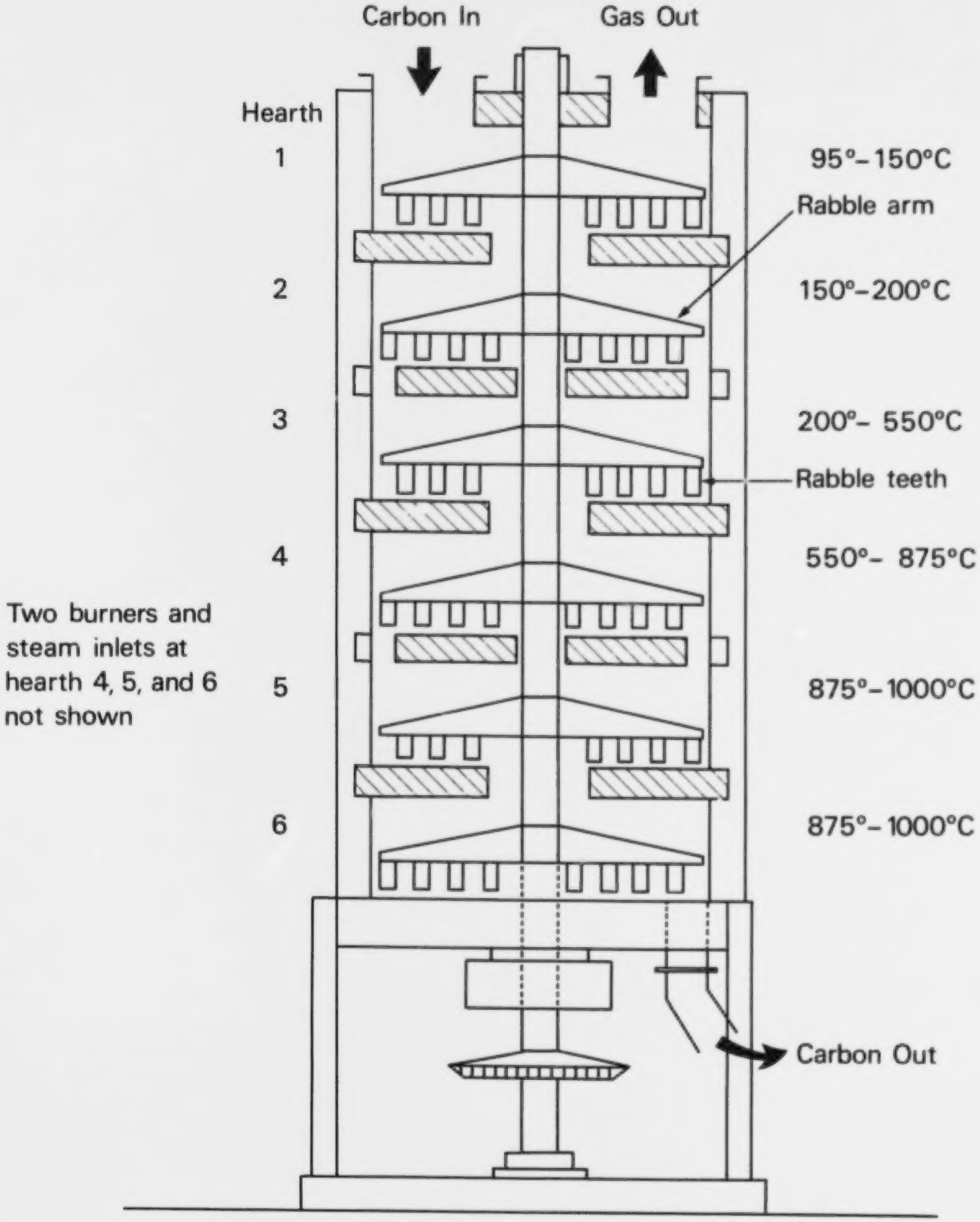
APPENDIX A21

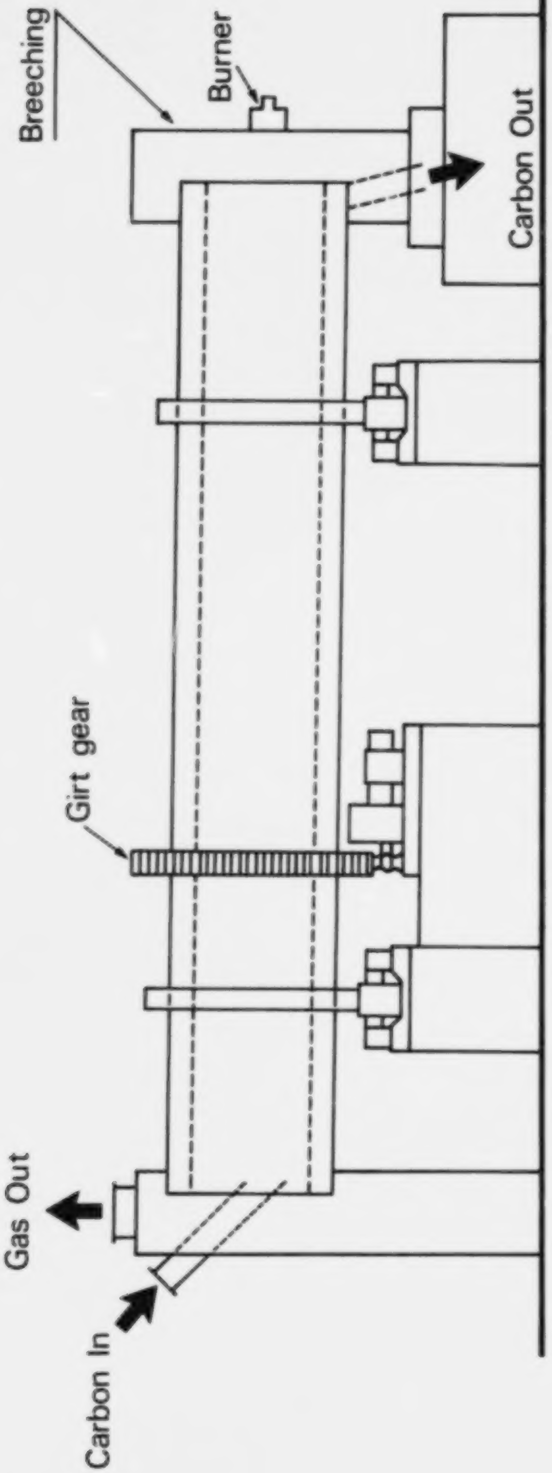
POWDERED ACTIVATED CARBON SYSTEM FOR SMALL COMMUNITIES (ENVIRONMENT CANADA)
INFLUENT AND EFFLUENT CHARACTERISTICS FOR DIFFERENT EXPERIMENTAL PERIODS

	BASELINE MEAN VALUES		ALUM + PAC + POLYMER MEAN VALUES		ALUM + PAC + POLYMER + RECYCLE MEAN VALUES	
	Influent (mg/l)	Effluent (mg/l)	Influent (mg/l)	Effluent (mg/l)	Influent (mg/l)	Effluent (mg/l)
TOC	22.3	20.8	24.0	11.4	16.1	6.1
BOD_5	120.8	68.4	117.9	14.1	77.8	11.8
P	4.8	3.8	6.0	0.25	4.14	0.38
SS	169.6	70.0	204.4	9.6	131.5	20.7

Multiple Hearth Regeneration Furnace

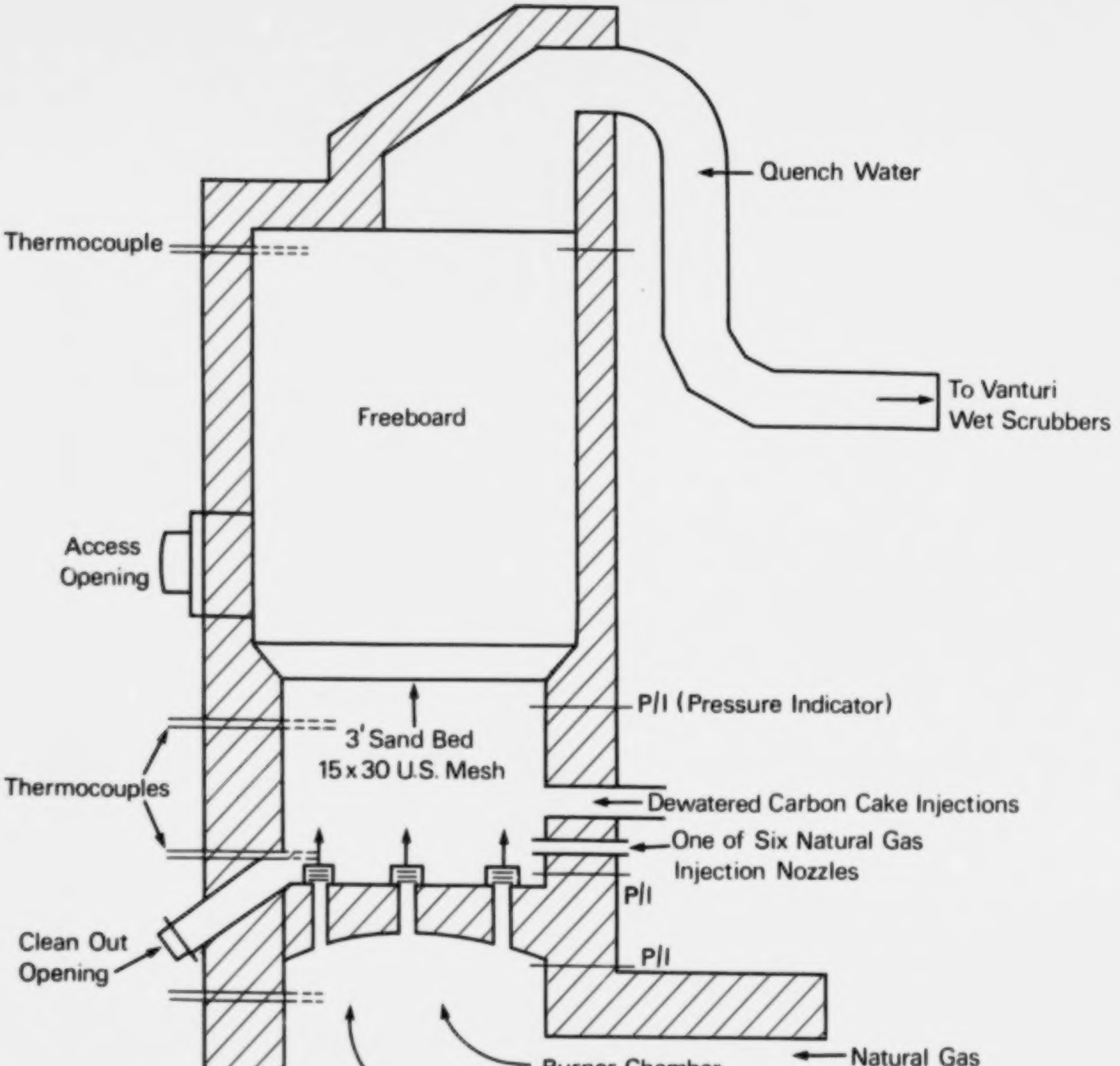
(from Loven, 1973)


Carbon In
Gas Out
Hearth
1
95°-150°C
Rabble arm
2
150°-200°C
3
200°- 550°C
Rabble teeth
4
550°- 875°C
Two burners and steam inlets at hearth 4, 5, and 6 not shown
5
875°-1000°C
6
875°-1000°C
Carbon Out


Breeching
Burner
Carbon Out
Girt gear
Gas Out
Carbon In

Rotary Kiln Regeneration Furnace (from Loven, 1973)

Fluidized Bed Regeneration Furnace


Quench Water
Thermocouple
To Vanturi
Wet Scrubbers
Freeboard
Access
Opening
P/I (Pressure Indicator)
3' Sand Bed
15 x 30 U.S. Mesh
Thermocouples
Dewatered Carbon Cake Injections
One of Six Natural Gas
Injection Nozzles
P/I
Clean Out
Opening
P/I
Natural Gas
Air
Burner Chamber
Fire Box

CARBON REGENERATION DATA, SOUTH TAHOE PUBLIC UTILITY DISTRICT

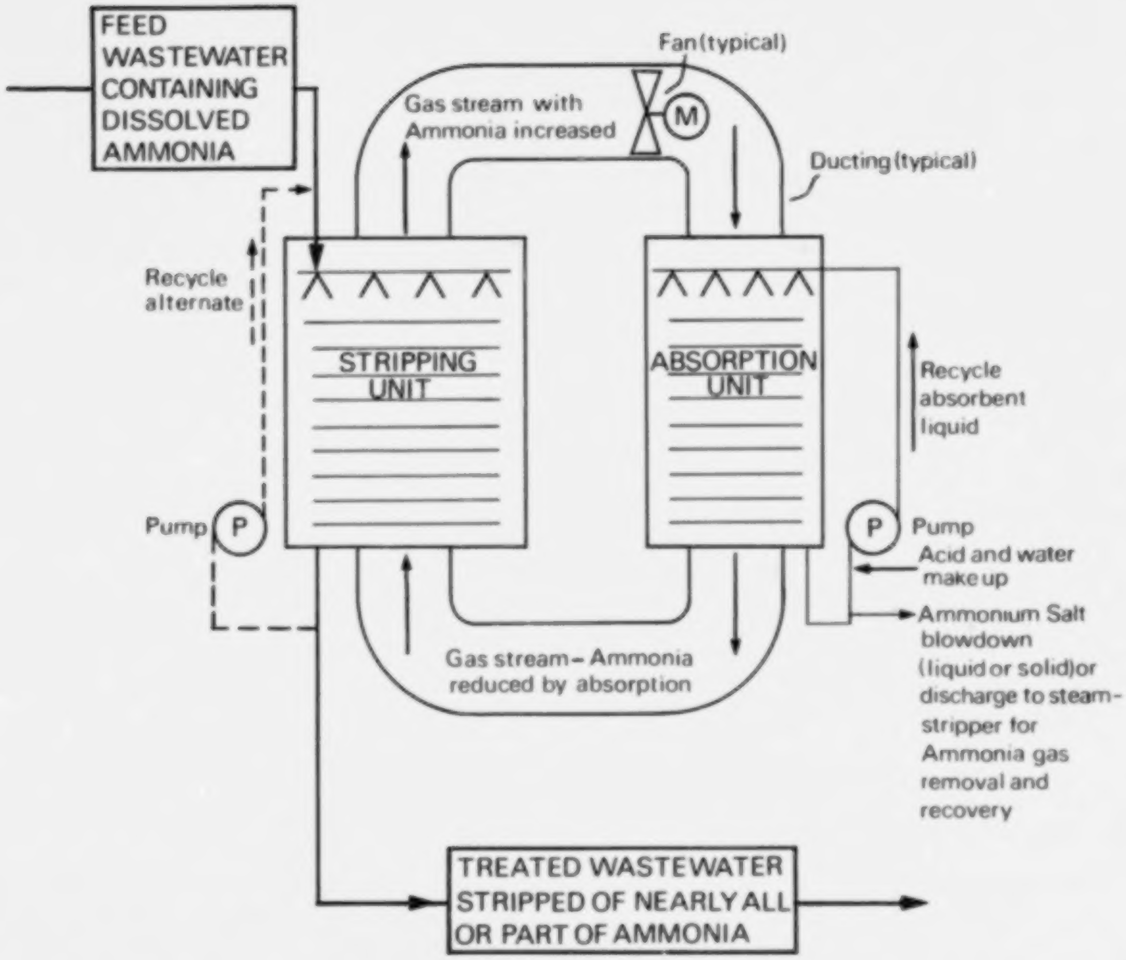
Date	Regeneration Cycle	Carbon	Carbon Feed (dry lb/hr)	kJ/kg (Btu per lb)	Apparent Density	Iodine No.	Ash (%)	FURNACE HEARTH TEMPERATURES, °C (°F) 1	2	3	4	5	6
11-18-69	First	Spent Regen.	217	7443 (3,200)	0.520 0.479	674 818	5.5 6.3	324 (635)	419 (805)	592 (1115)	875 (1620)	808 (1500)	886 (1640)
11-20-69	First	Spent Regen.	158	10350 (4450)	0.531 0.485	658 788	6.4 6.7	301 (595)	405 (780)	595 (1120)	881 (1630)	811 (1505)	886 (1640)
1-12-70	First	Spent Regen.	202	7710 (3315)	0.560 0.482	626 894	6.2 6.7	571 (720)	450 (860)	590 (1110)	889 (1645)	808 (1500)	903 (1670)
2-16-70	Second	Spent Regen.	176	8606 (3700)	0.577 0.486	539 860	6.4 7.2	396 (765)	492 (935)	640 (1200)	917 (1695)	836 (1550)	920 (1700)
2-20-70	Second	Spent Regen.	185	6722 (2890)	0.571 0.483	546 830	6.1 6.7	287 (570)	436 (835)	595 (1120)	912 (1685)	836 (1550)	912 (1685)
2-21-70	Second	Spent Regen.	162	8211 (3530)	0.570 0.479	607 874	5.7 6.3	332 (650)	452 (865)	657 (1230)	906 (1675)	830 (1540)	906 (1675)
1-3-70	Third	Spent Regen.	99	11793 (5070)	0.553 0.501	599 789	7.8 7.3	377 (730)	511 (970)	702 (1310)	884 (1635)	802 (1490)	884 (1635)
1-7-70	Third	Spent Regen.	177	9653 (4150)	0.515 0.488	676 823	7.6 7.3	419 (805)	528 (1000)	707 (1320)	881 (1630)	786 (1460)	892 (1650)
2-12-70	Third	Spent Regen.	119	2165 (5230)	0.580 0.488	524 816	6.5 7.7	436 (835)	553 (1045)	713 (1330)	917 (1695)	822 (1525)	
2-14-70	Fourth	Spent Regen.	116	11793 (5070)	0.580 0.487	528 820	6.4 7.1	447 (855)	584 (1100)	763 (1420)	917 (1695)	830 (1540)	917 (1695)

Note: Figures in brackets give the equivalent Imperial units.

CARBON REGENERATION DATA, POMONA, CALIFORNIA,

Carbon characteristics	Virgin	Spent carbon (Composite sample)			Regenerated carbon (Composite sample)					
					Before quenching			After quenching		
		1st Reg.	2nd Reg.	3rd Reg.	1st Reg.	2nd Reg.	3rd Reg.	1st Reg.	2nd Reg.	3rd Reg.
Iodine No., mg/g	1040	402	572	570	805	722	773	751	727	721
Apparent density, g/cm^3	0.484	0.629	0.585	0.594	0.528	0.537	0.526	0.565	0.548	0.535
Molasses No.	222	120	168	154	213	233	230	189	221	204
Methylene blue No. mg/g	259	147	153	153	223	243	246	227	239	245
Ash, %	6.4	10.3	8.22	8.67	10.7	11.6	7.81	12.0	12.2	9.0
Mean particle dia., mm	1.44	1.46	1.58	1.48	1.57	1.50	1.54	1.55	1.50	1.43
Max furnace temp °C.		1st Reg. 975	2nd Reg. 954	3rd Reg. 946						

United States process for Ammonia stripping and possible recovery


FEED WASTEWATER CONTAINING DISSOLVED AMMONIA
Fan (typical)
Gas stream with Ammonia increased
M
Ducting (typical)
Recycle alternate
STRIPPING UNIT
ABSORPTION UNIT
Recycle absorbent liquid
Pump
P
Pump
P
Acid and water make up
Ammonium Salt blowdown (liquid or solid) or discharge to steam-stripper for Ammonia gas removal and recovery
Gas stream – Ammonia reduced by absorption
TREATED WASTEWATER STRIPPED OF NEARLY ALL OR PART OF AMMONIA

DAVYHULME – LIMING OF ACTIVATED-SLUDGE (AS) EFFLUENT APPENDIX A27

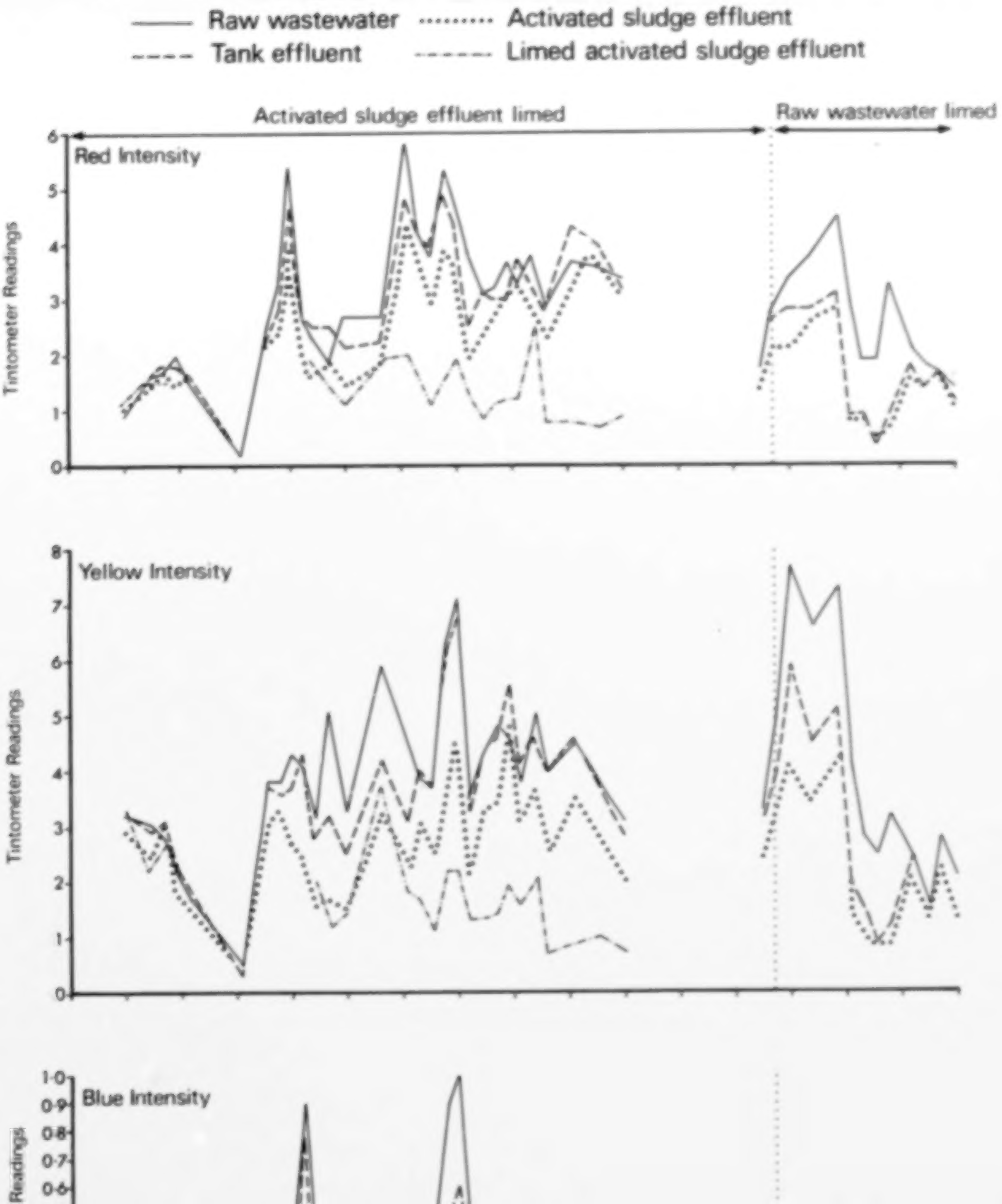
Degree of liming of AS effluent (parameters in mg/l)	AS effluent	After liming	% Removal
LIMING TO pH 11.5 (Lime dose 320)			
SS	28	63	125 INCREASE
BOD_5	14	9	35
COD	128	102	20
Total phosphorus (as P)	3.1	1.5	52
SLUDGE (kg/m^3 wastewater)			
Surplus activated		0.18	
Limed		0.80	
LIMING TO pH 11.75 (lime dose 577)			
SS	54	64	19 INCREASE
BOD_5	19	11	42
COD	166	108	35
Total phosphorus (as P)	3.3	1.9	42
SLUDGE (kg/m^3 wastewater)			
Surplus activated		0.21	
Limed		0.83	

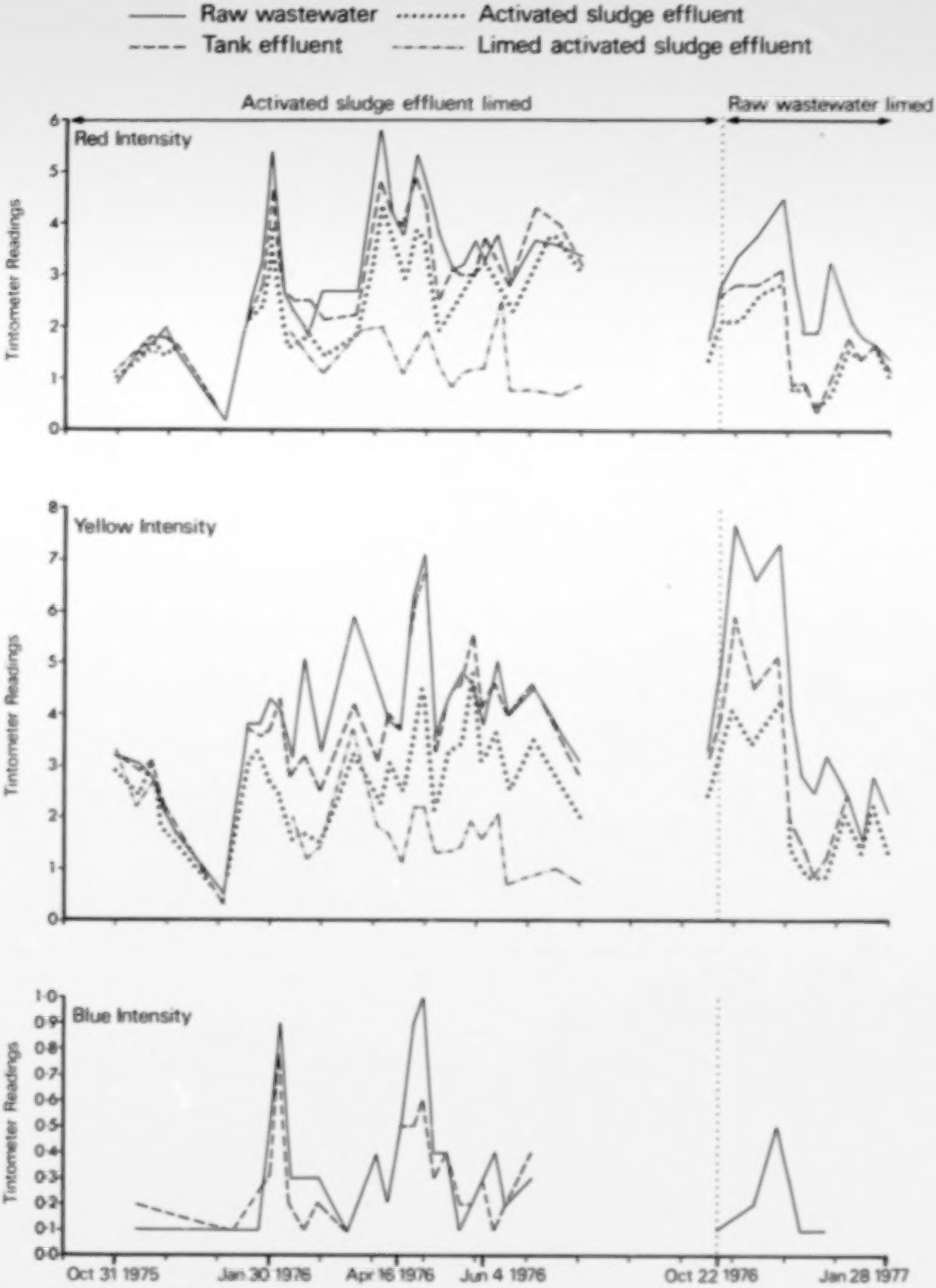
DAVYHULME – ACTIVATED-SLUDGE (AS) TREATMENT OF LIMED WASTEWATER APPENDIX A28

Degree of liming of raw wastewater (parameters in mg/l)	Raw w'water	Tank effl't	% Removal	AS effluent	% Removal	% Removal overall
NO LIMING (pH 7.3)						
SS	312	176	44	28	84	90
BOD_5	224	181	19	14	93	94
COD	597	448	25	128	71	79
Total phosphorus (as P)	5.1	4.9				
SLUDGE (kg/m^3 wastewater)						
Primary			0.32			
Surplus activated			0.18			
LIMING to pH 10 (lime dose 177)						
SS	516	101	80	23	87	96
BOD	309	175	43	19	89	94
COD	859	373	57	103	72	88
Total phosphorus (as P)	6.7	1.8	73	0.4	78	94
SLUDGE (kg/m^3 wastewater)						
Primary			0.48			
Surplus activated			0.08			
LIMING to pH 10.5 (lime dose 192)						
SS	299	57	81	12	79	96
BOD_5	252	154	39	11	93	96
COD	597	330	45	86	74	86
Total phosphorus (as P)	5.3	1.5	72	0.7	53	87
SLUDGE (kg/m^3 wastewater)						
Primary			0.49			
Surplus activated			0.09			
LIMING to pH 11 (lime dose 202)						
SS	315	62	80	11	84	97
BOD_5	290	198	32	12	94	96
COD	756	420	44	100	76	87
Total phosphorus (as P)	7.9	1.6	80	0.2	88	97
SLUDGE (kg/m^3 wastewater)						
Primary			0.54			
Surplus activated			0.11			
LIMING to pH 11.5 (lime dose 276)						
SS	321	66	79	12	82	96
BOD_5	286	193	33	20	90	93
COD	760	388	49	106	73	86
Total phosphorus (as P)	4.8	0.8	83	0.1	87	98
SLUDGE (kg/m^3 wastewater)						
Primary			0.62			
Surplus activated			0.03			

Appendix A29

Effects on colour of treatment given at Davyhulme pilot plant




Raw wastewater
Activated sludge effluent
Tank effluent
Limed activated sludge effluent
Activated sludge effluent limed
Raw wastewater limed
Red Intensity
Yellow Intensity
Blue Intensity
Tintometer Readings
0
1
2
3
4
5
6
7
8
0·0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
Oct 31 1975
Jan 30 1976
Apr 16 1976
Jun 4 1976
Oct 22 1976
Jan 28 1977

ALUM TRIALS AT GUELPH WASTEWATER TREATMENT WORKS

APPENDIX A30

1. PERFORMANCE (mg/l)

Phase and plant	Raw wastewater			Primary tank effluent			Final tank effluent			MLVSS*
	SS	COD	PO_4	SS	COD	PO_4	SS	COD	PO_4	
1 alum	176	398	18	147	333	17	20	93	2	1600
1 control	176	398	18	115	311	16	39	125	12	1300
2 alum	154	317	16	97	262	17	23	84	4	2050
2 control	154	317	16	101	272	16	16	84	12	2100
3 alum	137	294	15	96	248	15	25	83–	3	1900
3 control	137	294	15	89	248	16	25	99	11	1800
5 alum	236	451	20	128	311	17	39	121	4	2750
5 control	236	451	20	140	342	18	26	116	10	2350

* mixed liquor volatile suspended solids

2. REMOVALS (%)

Phase and plant	By primary settlement			By aeration			Total		
	SS	COD	PO_4	SS	COD	PO_4	SS	COD	PO_4
1 alum	17	17	8	86	72	87	87	77	88
1 control	35	22	9	66	60	24	78	68	31
2 alum	37	17	–	76	68	78	85	70	76
2 control	34	14	–	84	69	25	90	70	17
3 alum	30	16	–	74	67	78	82	72	78
3 control	35	16	–	72	60	31	82	66	27
5 alum	46	31	16	70	61	76	84	73	81
5 control	41	24	8	81	66	45	89	74	49

NOTE: No authenticated figures available for phase 4.

ALUM TREATMENT OF RAW WASTEWATER IN NORWEGIAN OXIDATION PONDS APPENDIX A31

PARAMETER	POND NUMBER, AND DETENTION (d)					
(mg/l where applicable)	1 29 d	2 13 d	3 3.3 d	4 22 d	5 8 d	6 2.7 d
	POST-DOSING WITH 154-185 mg/l alum			POND-DOSING WITH 140-167 mg/l alum		
SUSPENDED SOLIDS						
Oxidation pond effluent	88	65	66	64	42	32
% removal	66	75	74	75	84	87
Effluent given further settlement with 154-185 mg/l alum	9	25	16			
% Total removal	96	90	94			
COD						
Oxidation pond effluent	238	187	213	96	92	89
% removal	24	42	33	69	71	72
Effluent given further settlement with 154-185 mg/l alum	37	106	49			
% Total removal	87	66	85			
TOTAL NITROGEN						
Oxidation pond effluent	15.3	20.4	22.5	14.2	17.7	20.0
% removal	39	18	10	43	29	20
Effluent given further settlement with 154-185 mg/l alum	4.2	19.6	21.0			
% Total removal	82	21	16			
TOTAL PHOSPHORUS						
Oxidation pond effluent	4.2	5.1	5.4	1.2	0.64	0.66
% removal	28	12	7	79	89	89
Effluent given further settlement with 154-185 mg/l alum	0.10	0.54	0.42			
% Total removal	98	91	93			

Percentage removals all relate to raw wastewater
All work done under summer conditions.

TREATMENT OF ALUM-SETTLED WASTEWATER IN NORWEGIAN OXIDATION PONDS

PARAMETER	POND NUMBER, AND DETENTION (d)		
	7 29 d	8 13 d	9 3.3 d
(Feed was effluent from secondary settlement with alum)	PRE-DOSING with alum		
SUSPENDED SOLIDS			
Pond effluent (mg/l)	38	40	46
% Total removal from raw wastewater	85	84	82
COD			
Pond effluent (mg/l)	79	85	118
% Total removal from raw wastewater	75	73	62
TOTAL NITROGEN			
Pond effluent (mg/l)	10.3	14.3	17.8
% Total removal from raw wastewater	59	43	29
TOTAL PHOSPHORUS			
Pond effluent (mg/l)	0.42	0.45	0.74
% Total removal from raw wastewater	93	92	87

All work was done under summer conditions

FLOWS AND CARBON-ADSORPTION STAGES OF SOME US WORKS COMBINING BIOLOGICAL AND PHYSICAL-CHEMICAL TREATMENT

Serial	Works	Commiss-ioned	Average flow m^3/d $\times 10^3$	Details of carbon section					
				Column type	No.	Total contact time (min)	Hydr. load m^3/m^2d (gpm/ft^2)	Depth (m)	Effluent standard required (mg/l)
1	Arlington		135	DG	1	38	204.3 (2.9)	4.6	BOD_5 under 3
2	Colorado Springs	1970	44	D	2	30	352.3 (5)	6.1	BOD_5 under 2
3	Dallas		454	UP	1	10	563.7 (8)	3.1	BOD_5 under 10
4	Fairfax County		163	DG	1	36	211.4 (3)	4.6	BOD_5 under 3
5	Montgomery County		272	UP	1	30	458.0 (6.5)	7.9	BOD_5 under 1
6	Occoquan		82	UP	1	30	408.7 (5.8)	7.3	BOD_5 under 1 COD under 10
7	Orange County	1975	68	UP	1	30	408.7 (5.8)	7.3	COD under 30
8	Los Angeles		23	DG	2	50	281.8 (4)	7.9	COD under 12
9	Piscataway	1973	23	D Pr	2	37	458.0 (6.5)	9.8	BOD_5 under 5
10	St. Charles		25	DG	1	30	260.7 (3.7)	4.6	
11	South Lake Tahoe	1968	34	UP	1	17	436.9 (6.2)	4.3	BOD_5 under 5

D = downflow
G = gravity

U = upflow
P = packed

Pr = pressure

Total contact time = empty bed (superficial) contact time for average plant flow

carbon size 8 x 30 in all cases

SOUTH LAKE TAHOE WASTEWATER TREATMENT WORKS TYPICAL EFFLUENT QUALITIES AT VARIOUS STAGES

Stage	SS (mg/l)	BOD_5 (mg/l)	COD (mg/l)	Total P (mg/l)	Turbidity JU	MBAS (mg/l)	Coli-forms
Raw wastewater	230	300	280	12	250	7	50m*
Primary tank effluent	100	100	220	9	150	6	15m*
Activated-sludge effluent	26	30	40	6	50	2	2.5m*
Effluent from lime-aided settlement	10			2	10		
Multi-media filter effluent	0	3	25	0.1	0.3	0.5	50
Carbon column effluent	0	1	10	0.1	0.3	0.1	50
Chlorinated final effluent	0	0.7	10	0.1	0.3	0.1	2

*m = million

Appendix A35

South Lake Tahoe Wastewater Treatment Works — Some Design Parameters

1. Feed

Average design flow (dwf)	33750 m^3/d
Peak flowrate except as below	67500 m^3/d
Peak flowrate filters and carbon columns	37000 m^3/d
Summer design BOD_5	325 mg/l
Winter design BOD_5	250 mg/l
Summer design suspended solids	200 mg/l
Winter design suspended solids	150 mg/l
Summer wastewater temperature	17°C

2. Conventional Activated Sludge Treatment

Primary settlement tanks, upward flowrates	
12000 m^3/d (one tank)	2.4 m/h
Balance of flow (one tank)	1.2 m/h
Activated sludge reactors, detention	
12000 m^3/d (three tanks, plug flow)	6.4 h
Balance of flow	5.0 h
Activated sludge reactors, BOD loadings	
12000 m^3/d	800 kg/1000 m^3
Balance of flow	1120 kg/1000 m^3
Secondary settlement tanks, upward flowrates	1.4 m/h
Activated sludge recirculation rate	1 dwf
Sludge quantities — dry solids	
Primary	3700 kg/d
Surplus activated	4400 kg/d

3. Lime-Aided Settlement

Flashmixer detention	30 seconds
Flocculator detention (with air mix)	4.5 minutes
Chemical feed equipment	
Recalcined lime	680 kg/h
Make-up lime	680 kg/h
Lime-aided settlement tank, upward flowrate 1.9 m/h	
Lime sludge thickener	
Flowrate	240 m^3/h
Upward flow rate	2 m/h
Surface dry solids loading	980 kg/d/m^2
Thickened sludge solids	8-20%

4. Ammonia Stripping Tower (cross-flow)

Flowrate	17000 m^3/d
Packing	
Area	84 m^2
Height	7.3 m
Splashbars	9.5 mm x 25-37 mm

Spacing horizontal	34 mm
vertical	50 mm

5. **Two-Stage Recarbonation**

Carbon dioxide compressors, total	70m^3/minute
Reaction tank detention	0.5 h
Upward flowrate	5 m/h

6. **Balancing Ponds**

Total capacity	11000m^3

7. **Multi-Media Filters (three sets of two series beds)**

Total peak flowrate	37000 m^3/d
Hydraulic loading	12 m^3/m^2/h
Backwash rate	43 m^3/m^2/h

8. **Carbon Columns (eight, upflow, counter current)**

Total peak flowrate	37000 m^3/d
Effective depth of carbon	4.3 m
Contact time	17 minutes
Hydraulic loading	19 m^3/m^2/h

9. **Chlorination Equipment (three feeders)**

Total capacity of feeders	2700 kg/d

10. **Carbon Regeneration**

Dry carbon capacity	2700 kg/d

11. **Sludge Dewatering and Incinerating Equipment**

Concurrent-flow centrifuges	0.6 m x 1.5 m
Organic sludge (2 no)	
Total dry solids capacity	200 kg/h
Lime sludge (1 no)	
Capacity	750 kg/h
Sludge incineration furnace	
6-hearth, diameter	4.3 m
dry solids capacity	400 kg/h
Lime recalcining furnace	
6-hearth, diameter	4.3 m
Dry CaO capacity	10,000 kg/d

BOURGENAY WASTEWATER TREATMENT WORKS, COMMUNE OF SAINT-HILLAIRE, VENDEE

APPENDIX A36

DESIGN CRITERIA (based on 1980 populations)

	Winter	Summer
Dry-weather flow (m^3/d)	50	600
Peak rate (m^3/h)	7.5	50
Wastewater		
Suspended solids (kg/d)	28	280
BOD_5 (kg/d)	24	240
Effluent standard required (mg/l)		
Suspended solids	30	30
BOD_5	30	70

'Separate' sewerage system

DESIGN OPERATING DATA

Alum consumed	–	90 kg/d
Polyelectrolyte consumed	–	0.6 kg/d
Lime consumed in sludge treatment	–	50 kg/d
Total chemical costs	–	66 Fr/d
Electricity consumed (kWh/d)	46	208
Electricity cost (1975/76)	6 Fr/d	27 Fr/d

WUPPERTAL PARALLEL TEST-RUNS (INDUSTRIALISED WASTEWATER) APPENDIX A37/1

		I		II	
		Oxygen	Air	Oxygen	Air
Flow (m^3/d)		3.15	24.0	9.75	26.0
Retention	(h)	6.2	6.5	2.0	6.0
BOD_5 of influent	(mg/l)	348	324	211	211
BOD_5 of effluent	(mg/l)	18	97	31	35
COD of influent	(mg/l)	787	751	517	517
COD of effluent	(mg/l)	176	281	219	219
Concentration of DO	(mg/l)	16.2	0.5-2.0	14.7	1.0-3.0
Oxygen utilization (kg/kg red)		1.1	–	–	–
BOD_5 loading (kg/m^3d)		1.39	1.20	2.53	0.84
MLSS (mg/l)		5200	4400	5100	3500
Biomass loading (kg/kg d)		0.28	0.27	0.49	0.24
Excess sludge (kg/kg red)		0.52	0.91	0.40	0.87
Sludge index (ml/g)		64(1)	152(2)	73(1)	182(2)

(1) Sludge volume with stirring (1 rev/min)

(2) Mohlmann index (about 25 ml/g higher than index with stirring).

DAVYHULME PARALLEL TEST-RUNS (INDUSTRIALISED WASTEWATER)

	4.2.74 to 7.3.74		13.3.74 to 5.4.74	
	CM (1) oxygen	Air	CM (1) oxygen	Air
Feed:				
BOD_5 (mg/l)	248		256	
COD (mg/l)	593		661	
SS (mg/l)	117		131	
Amm. N (mg/l)	23		37	
pH	7.2-8.8		6.6-7.7	
Retention (h):	1.9	1.9	2.5	3.9
Sludge return rate (percentage feed)	55	66	52	79
MLSS (mg/l)	3610	3460	4085	3670
Sludge loading (g BOD_5/g MLSS d)	0.8	0.9	0.6	0.4
Si Sludge age (d)	3	2	3	3
SVI (ml/g)	69	72	64	93
Effluent:				
BOD_5 (mg/l)	59	112	41	52
COD (mg/l)	235	327	241	236
SS (mg/l)	67	83	55	60
Amm. N. (mg/l)	20	18	30	28
pH	6.5-7.8	7.1-8.3	6.5-7.2	6.7-7.6
Sludge production (kg/kg BOD_5 removed)	0.6	1.0	0.6	0.9
kg O_2 used/kg BOD_5 removed	1.1	–	1.25	–

(1) CM = completely-mixed plant.

OXYGEN TREATMENT OF BAVARIAN CARCASSING-HOUSE WASTES

APPENDIX A37/3

	I	II(2)	III(3)
Flow (m^3/d)	0.4	0.72	37.0
Retention (h)	60	33	87.3
BOD_5 of influent (mg/l)	5655	2640	1900
BOD_5 of effluent (mg/l)	111	98	6
COD of influent (mg/l)	9980	–	1570
COD of effluent (mg/l)	364	294	86
Concentration of DO (mg/l)	10-12	10-12	
Oxygen utilization (kg/kg red)	0.83	0.83	
BOD_5 loading (kg/m^3 d)	2.2	1.9	0.52
MLSS (mg/l)	9000	9400	7000
Biomass loading (kg/kg d)	0.25	0.20	0.08
Excess sludge (kg/kg red)	0.09	0.09	
Sludge index (ml/g) (1)	273	250	137
Influent Amm. N. (mg/l)	1140	611	
Effluent Amm. N. (mg/l)	1109	442	

(1) Sludge volume after 30 min, diluted 1:3 to 1:4 plus stirring (2 rev/min).

(2) Diluted with clean water 1:1, only a few values.

(3) Dilution 1:1.34

OXYGEN TREATMENT OF BERLIN SLUDGE HEAT-TREATMENT LIQUORS

APPENDIX A37/4

	I	II
Flow (m^3/d)	1.20	1.68
Retention (h)	20	14
BOD_5 of influent (mg/l)	7340	5790
BOD_5 of effluent (mg/l)	103	63
Concentration of DO (mg/l)	10	10
Oxygen utilization (kg/kg red)	1.52	1.52
BOD_5 loading (kg/m^3d)	8.8	9.7
MLSS (mg/l)	15100	10800
Biomass loading (kg/kg d)	0..58	0.90
Sludge index (ml/g) (1)	~ 200	~ 200

(1) Sludge volume after 30 min, diluted.

OXYGEN TREATMENT OF MAINLY DOMESTIC WASTEWATER AT MUNICH

APPENDIX A37/5

	I	II (1)
Flow (m^3/d)	110.4	139.2
Retention (h)	2.4	1.9
BOD_5 of influent (mg/l)	232	238
BOD_5 of effluent (mg/l)	12	12
COD of influent (mg/l)	404	419
COD of effluent (mg/l)	65	47
Concentration of DO (mg/l)	14	13
Oxygen utilization (kg/kg red)	1.1	0.8
BOD_5 loading ($kg/m^3 d$)	2.4	3.0
MLSS (mg/l)	7500	7000
Biomass loading (kg/kg d)	0.32	0.43
Excess sludge (kg/kg red)	0.46	0.86
Sludge index (ml/g) (2)	40	34

(1) Unsettled wastewater feed

(2) Sludge volume after 30 min, with stirring (1 rev/min)

	13.8.73 to 31.8.73		17.9.73 to 30.9.73	
	ST	CM	ST	CM
Feed:				
BOD_5 (mg/l)	157		220	
SS (mg/l)	94		105	
Amm. N. (mg/l)	27		28	
pH	6.4-8.0		7.1-7.6	
Retention (h)	2.5	2.5	3.7	3.8
Sludge return rate (per cent feed)	62	66	51	65
MLSS (mg/l)	4420	4830	5045	4620
Sludge loading (g BOD_5/g MLSS d)	0.3	0.3	0.3	0.3
Sludge age (d)	4	5	7	7
Effluent:				
BOD_5 (mg/l)	16	11	24	20
SS (mg/l)	18	18	26	17
Amm. N (mg/l)				
pH	6.4-7.6	6.5-7.4	6.7-7.3	6.6-7.1
Sludge production (kg/kg BOD_5 removed)	0.8	0.7	0.6	0.6
SVI (ml/g)	124	85	94	183
kg O_2 used/kg BOD_5 removed	1.4	1.7	–	–

ST = staged plant CM = completely-mixed plant

OXYGEN TREATMENT OF DOMESTIC WASTEWATER AT BATH, AT STEADY AND DIURNALLY-VARYING RATES

APPENDIX A37/7

	Steady rate	Diurnal rates	Diurnal rates (1)
Feed:			
BOD_5 (mg/l)	179	64-128	356
SS (mg/l)	179	40-110	378
Amm. N. (mg/l)	25	21- 34	50-104
Retention period in first stage reactors (h)	1.1	0.7-1.3	1.3-2.2
MLSS (mg/l)	2900	1430-3010	5300-10400
Sludge loading (g BOD_5/g MLSS d)	1.3	3.2-0.45	1.3-0.35
Sludge age (d)	1.1	1.2	3.3
Effluent from first stage:			
BOD_5 (mg/l)	21	16	25
SS (mg/l)	22	22	25
Amm. N (mg/l)	20	23	–
Retention period in second stage reactors (h)	3.4	2.1-3.4	2.1-3.2
MLSS (mg/l)	3000	3350-3440	3000
Sludge loading (g BOD_5/g MLSS d)	0.05	0.06-0.03	0.1-0.06
Sludge age (d)	30	21	21
Effluent from second stage:			
BOD_5 (mg/l)	11	6	8
SS (mg/l)	13	13	11
Amm. N (mg/l)	0.1	0.1	2

(1) unsettled wastewater feed

COLESHILL PARALLEL TEST-RUNS

APPENDIX A37/8

9.8.72 – 7.9.72

	Oxygen	Air
Feed:		
BOD_5 (mg/l)	131	
COD (mg/l)	558	
SS (mg/l)	312	
Amm. N (mg/l)	36	
pH	6.9	
Retention (h)	c 6.6	c 7
MLSS (mg/l)	7000	5454
Sludge loading (g BOD_5/g MLSS d)	0.13	c 0.15
Sludge age (d)	9	(9)
Temperature (°C)	17.5	18.4
Effluent:		
BOD_5 (mg/l)	21	29
COD (mg/l)	138	131
SS (mg/l)	74	83
Amm N. (mg/l)	32	5
Oxidized N (mg/l)	1	31
pH	6.9	7.1

TWO-STAGE TREATMENT OF INDUSTRIALISED WASTEWATER AT COLESHILL. FIRST STAGE ON OXYGEN, SECOND STAGE ON AIR

APPENDIX A37/9

	7.2.73
Feed:	
BOD_5 (mg/l)	175
COD (mg/l)	430
SS (mg/l)	228
Amm. N (mg/l)	(33)
pH	7.3
Retention period in first stage reactors (h)	1.8
MLSS (mg/l)	5650
Sludge loading (g BOD_5/g MLSS d)	0.4
Temperature (°C)	11
Effluent from first (oxygen) stage	
BOD_5 (mg/l)	27
SS (mg/l)	37
Amm. N (mg/l)	30
Oxidized N (mg/l)	1
pH	6.8
Retention period in second stage reactors (h)	4.9
MLSS (mg/l)	7180
Sludge loading (g BOD_5/g MLSS d)	0.02
Effluent from second (air) stage	
BOD_5 (mg/l)	10
SS (mg/l)	26
Amm. N (mg/l)	30
Oxidized N (mg/l)	3
pH	7.2

OXYGEN TREATMENT OF DOMESTIC WASTEWATER AT DAVYHULME, WITHOUT AND WITH SODIUM HYDROXIDE DOSING

APPENDIX A37/10

	15.10.73 to 22.10.73 without NaOH	12.11.73 to 23.10.73 with NaOH (1)
Feed:		
BOD_5 (mg/l)	158	190
SS (mg/l)	94	89
Amm. N (mg/l)	26	25
pH	6.9-7.5	7.0-7.8
Retention (h)	5.7	5.8
Sludge return rate (percentage feed)	61	64
MLSS (mg/l)	5320	6985
Sludge loading (g BOD_5/g MLSS d)	13	0.11
Sludge age (d)	18	26
Temperature (°C)	15	15
Effluent:		
BOD_5 (mg/l)	19	26
SS (mg/l)	28	20
Amm. N (mg/l)	20	7
Nitrate-N (mg/l)	4	13
pH	6.6-7.3	7.3-8.0
Sludge production (kg/kg BOD_5 removed)	0.5	0.4
SVI (ml/g)	165	139

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(1) NaOH dose about 1 kg/kg BOD_5 removed.

OXYGEN TREATMENT OF DAIRY WASTES AT CONS-LA-GRANVILLE

APPENDIX A37/11

COD of feed (mg/l)	kg COD/m^{3}d	Percentage CO$_2$ in gas space: pH in mixed liquor compartment of reactor		
		1	2	3
1850	3.7	36 6.20	46 6.10	50 6.10
270	0.56	17 6.0	23 5.95	22 5.90
955	2.15	16 –	23 –	24 –
1350	2.86	19 6.20	28 6.20	30 6.10
2200	4,44	12 6.10	19 6.10	22 6.05
2360	5.05	21 6.10	30 6.05	45 6.15
1700	3.26	47 6.15	55 6.05	65 6.00

MULTI-STAGE TREATMENT OF DAIRY WASTES AT CONS-LA-GRANVILLE FIRST AND THIRD STAGES ON OXYGEN, SECOND STAGE ON AIR

APPENDIX A37/12

COD of feed (mg/l)	kg COD/m^{3}d	pH in mixed liquor compartment of reactor		
		1 Oxygen	2 Air	3 Oxygen
2360	5.4	6.25	6.90	6.80
884	2.4	6.25	6.85	6.55
995	3.05	6.70	7.25	6.80
1000	2.90	6.55	7.00	6.70
1015	3.20	6.70	7.00	6.70
1430	3.50	6.75	7.20	6.80
1575	4.60	6.05	6.65	6.45
875	2.50	6.40	7.25	6.40

OXYGEN TREATMENT OF DOMESTIC WASTEWATER AT LAS VIRGENES, LOS ANGELES

APPENDIX A37/13

	Feed BOD_5 (mg/l)	Loading (g BOD_5/g MLSS d)	Sludge age (d)	°C	(%) Amm. nitr. removed	Nitr-N in effl. (mg/l)
1	82	0.07	79	21/35	97	16.2
2	69	0.11	68	23/26	99	15.3
3	79	0.15	46	18/19	98	3.8
4	107	0.24	30	18/19	71	6.9
5	115	0.33	12	19/21	69	5.6
6	103	0.41	9	20/22	82	7.5
7	95	0.46	12	21/24	80	8.0

OXYGEN TREATMENT OF INDUSTRIALISED WASTEWATER AT GOEPPINGEN

APPENDIX A37/14

	III	IV
Flow (m^3/d)	9.2	7.75
Retention (h)	2.2	2.6
BOD_5 of influent (mg/l)	302	181
BOD_5 of effluent (mg/l)	17	10
COD of influent (mg/l)	318	300
COD of effluent (mg/l)	71	56
Concentration of DO (mg/l)	7.2	10.4
Oxygen utilisation (kg/kg red)	0.94	1.2
BOD_5 loading (kg/m^3 d)	3.3	1.7
MLSS (mg/l)	5800	6600
Biomass loading (kg/kg d)	0.56	0.26
Excess sludge (kg/kg red)	0.35	0.31
Sludge index (ml/g) (1)	45	44

(1) Sludge volume after 30 min, with stirring (1 rev/min)

OXYGEN TREATMENT OF INDUSTRIALISED WASTEWATER AT ROTHERHAM

APPENDIX A37/15

	I	II
Feed:		
BOD_5 (mg/l)	126	223
COD (mg/l)	372	541
SS (mg/l)	65	124
Retention (h)	2	2
MLSS (mg/l)	7050	6200
Sludge loading (g BOD_5/g MLSS d)	0.22	0.45
Specific growth rate (d^{-1})	0.15	0.10
Effluent:		
BOD_5 (mg/l)	19	32
SS (mg/l)	23	53
Nitrate—N (mg/l)	1	–
Sludge production (kg/kg BOD removed)	1	0.6
SVI (ml/g)	115	67

OXYGEN USED IN US EXPERIMENTAL PLANTS

APPENDIX A37/16

	Plant/ phase	Loading (g BOD_5/g MLSS d)	kg O_2 supplied/ kg BOD_5 removed	kg O_2 supplied/ kg COD removed	Notes
Newtown Creek (New York)	2	0.57	1.20	0.59	
	3	0.57	1.39	0.65	
	4	0.92	1.02	0.55	
	5	1.19	0.88	0.72	
	6	1.62	0.83	0.73	
	7	2.44	0.79	0.61	
Batavia	1	0.59	0.94	0.60	
	2	0.87	1.36	1.13	(1) (2)
Blue Plains	1	0.97	1.04	0.60	(2)
	2	0.36	2.09	1.03	(3)
FMC (Denver)	4	0.69	1.22	0.72	(4)
	5	1.17	1.11	0.65	(4)
	6	1.01	0.92	0.75	(4)
	7	0.91	1.08	0.78	(4)

(1) O_2 consumptions high because high final tank loadings resulted in lowered BOD_5, COD removals

(2) effluents not nitrified

(3) effluents substantially nitrified

(4) open-topped plant

French Work on Tannery Wastes

1. Introduction

1.1. Oxygen activated-sludge treatment was found particularly suitable for tannery wastes, which have wide variations in oxygen demand, high pH values, and can contain much sulphur. Conventional treatment methods involve pH — correction and/or 24 hour homogenisation/balancing, primary settlement, and aeration in activated-sludge reactors for at least 8 hours, or in lagoons with 2-3 days detention. These processes are often accompanied by objectionable smells.

2. OAS Treatment

2.1. The oxygen activated-sludge pilot plant for treating tannery wastes consisted of a circular primary settlement tank with upward-flow velocity 1.5-2.0 m/h, a single-stage circular OAS reactor 5m^3 in capacity giving about 2 hours retention, and a circular final settlement tank with upward-flow velocity about 9 m/h.

2.2. Oxygen gas was recycled through perforated tubes or porous domes in the reactor floor, and also served to agitate the mixed liquor, giving considerable savings in power consumed. The gas recycling rate was about 7.5 m^3/h, or 1.5 m^3 gas/m^3 reactor/h, average oxygen content being 60% for a dissolved oxygen level of 2.5 mg/l.

2.3. The tannery operated between 0.500 and 2100 hours, during which time loads could vary by a factor of 8. Some domestic wastewater was also present throughout each day, amounting to about 20% of the volume of the feed.

2.4 Typical results were:

Parameter (mg/l except for pH)	Primary tank effluent	Final effluent	Average % removal
pH	7.2-12.2	6.2-8.0	–
Suspended solids	752	30-105	–
BOD_5	345 (max 650)	31	91
COD	877 (max 1300)	119	86
TOD	860	174	80
Sulphurs	50 (max 100)	neglig.	100

2.5 Recirculated gases included carbon dioxide developed during the biological treatment, which helped to reduce feed pH, and no other neutralisation was adopted.

2.6. When additional neutralisation of the feed was experimentally tried, to pH 7-7.5, final effluent pHs were between 5.5 and 6.2.

2.7. MLSS were normally maintained at about 7500-8000 mg/l. Oxygen utilisation was 96-97%, 1 kg oxygen being needed to remove 1 kg BOD_5 0.22 kg of the oxygen maintained the activated sludge balance, 0.78 kg oxidised the incoming pollution load including all the sulphurs. Surplus activated-sludge was about 0.7 kg/kg BOD_5 removed.

2.8. For comparison, atmospheric air instead of 'pure' oxygen, was injected into the system. To maintain the same oxygen supply and a similar dissolved oxygen level (about 2.5 mg/l), about 5.5 m^3 air/m^3 reactor/h was needed — ie about 27 m^3/h. Turbulence was high and the bacterial floc soon became unacceptably disturbed. Further experiments showed that only about 0.6m^3 gas or air/m^3 reactor was needed to maintain suspension and provide mixing.

2.9. Compared with conventional aeration practice on tannery effluent, oxygen activated-sludge allowed biomass loadings to be increased from 0.300 to 0.485 g BOD_5/g MLSS/d, and MLSS to be increased from 4000 to 8000 mg/l.

2.10. Both oxygen activated-sludge and air plant sludge settled well.

2.11. The reactor was sealed and there was little or no smell.

RECENT INFORMATION ON OXYGEN ACTIVATED-SLUDGE PERFORMANCE IN THE FEDERAL REPUBLIC OF GERMANY

APPENDIX A39

1. WASTEWATER TREATMENT AT GOEPPINGEN; BREISGAUER-BUCHT AND WUPPERTAL – RUTENBECK

Serial		Goeppingen	Br-Bucht	Wuppertal Rutenbeck
1	Type of wastewater	Municipal	Municipal	Chemical industry
2	Design flow, m^3/d	39,000	153,000	20,000
3	Design BOD_5 load, kg/d	11,000	42,000	35,000
4	Works completion date	May '78	1979	1977
5	Intended final effluent BOD_5 standard (not exceeding, mg/l)	20	20	–
6	Primary settlement detention (h)	1.2	1.5	nil
7	First oxygen activated-sludge reactors			
	Detention (h)	3	2.7	7.5
	kg BOD_5/kg total solids/d	0.3	0.3	0.7
	Mixed liquor solids, kg/m^3	6	6	8
	kg $BOD_5/m^3/d$	1.7	1.7	5.6
8	Intermediate settlement detention (h)	–	–	5.3
9	Second oxygen activated-sludge reactors			
	Detention (h)	–	–	3.8
	kg BOD_5/kg total solids/d	–	–	0.2
	mixed liquor solids, kg/m^3	–	–	4
	kg $BOD_5/m^3/d$	–	–	0.8
10	Final settlement detention (h)	3.1	4.2	5.8
11	Oxygen production (t/d)	16	78	65
12	Power requirements (kWh/kgO_2)			
	For oxygen production	–	0.345	–
	For oxygen transfer	–	0.221	–
	Total	0.723	0.566	0.500
	Per head of equivalent population (kWh)	11.6	9.1	8.0

2. Treatment works with a design flow of 67,500 m^3/d and a 16 mg/l BOD_5 final effluent requirement will be completed in 1979/80 at Bonn, where the primary settlement tanks and sludge treatment units are already operating. Works with a design flow of 55,000 m^3/d are planned at Bremerhaven.

Technical Aspects of the use of Oxygen in a Wastewater Pumping Main

To maintain aerobic conditions in a pumping main the oxygen demands of respiring micro-organisms in the slimes on the walls of the main and in the wastewater itself need to be satisfied. These rates of uptake which are very variable, depend among other things on temperature, pH and concentrations of inhibitory substances in the wastewater, should be established by laboratory and site investigation. A 'young' domestic sewage which has newly entered a sewerage system may have an uptake rate of only 2 mg/l h at 15°C whereas figures of up to 20 mg/l may apply to 'old' wastewaters. Average uptake rates in the United Kingdom are about 6 mg/l h by the micro organisms in wastewater and about 700 mg/m^2 h by those in slimes on walls.

The daily weight of dissolved oxygen may be estimated from the equation

$$W = \left[R + \frac{2800}{D}\right] \times \frac{6\pi D^2 L}{10^9}$$

L = pumping main length (m)

W = weight of dissolved oxygen, kg/d

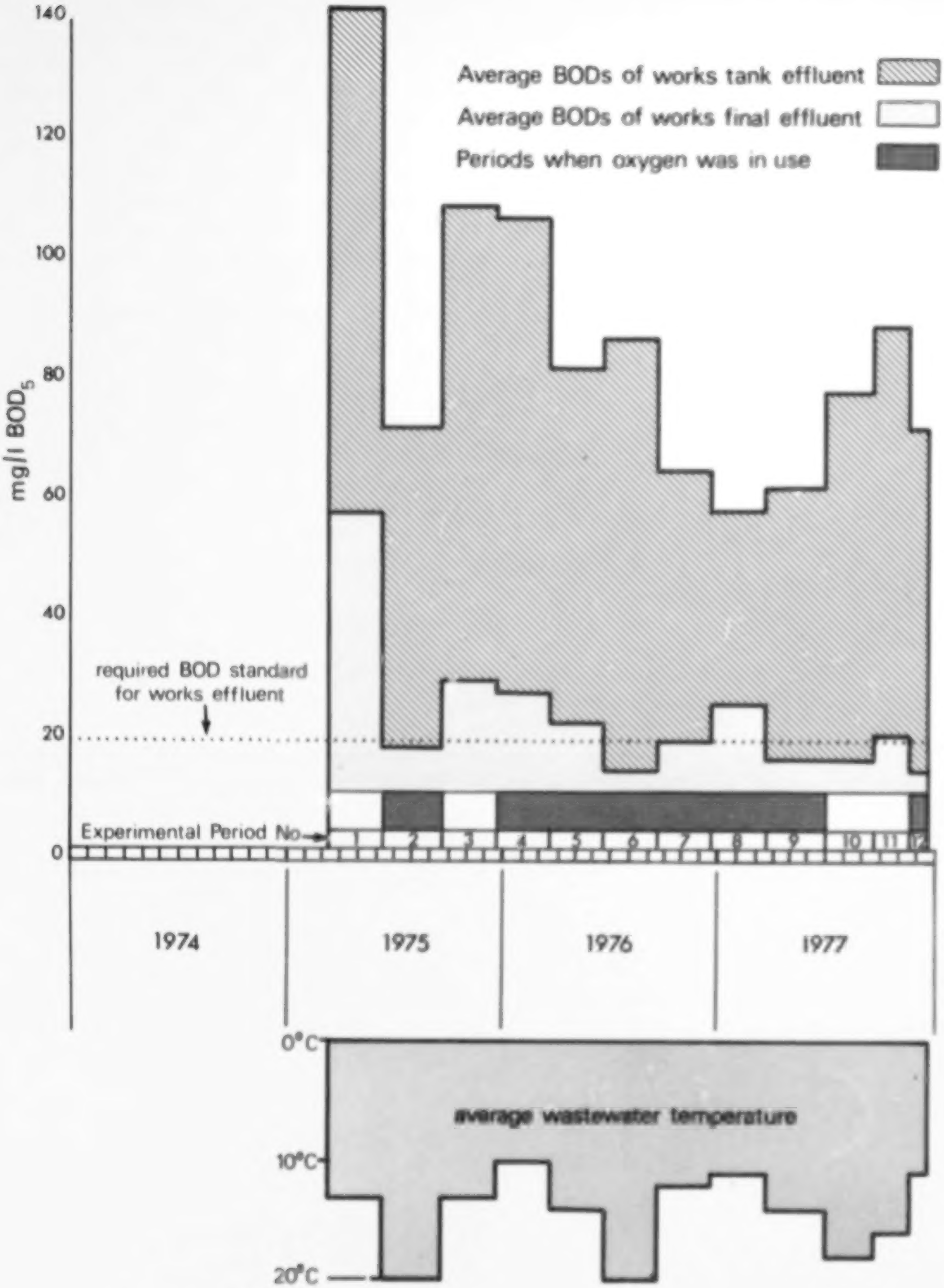
R = wastewater respiration rate at 15°C (mg/l/h)

D = pumping main diameter (mm)

Because retention-time in the main decreases as wastewater velocity increases, W is independent of quantity pumped.

The effect of temperature may be taken into account by multiplying W by $1.07^{(T-15)}$ where T is the wastewater temperature in °C. W need never exceed the total daily BOD_5 load of the wastewater.

Effect on works performance from injecting oxygen into the Bath Wastewater Pumping Main



PERFORMANCE OF BATH PRIMARY SETTLEMENT TANKS WITH AND WITHOUT OXYGEN INJECTION INTO BATH PUMPING MAINS

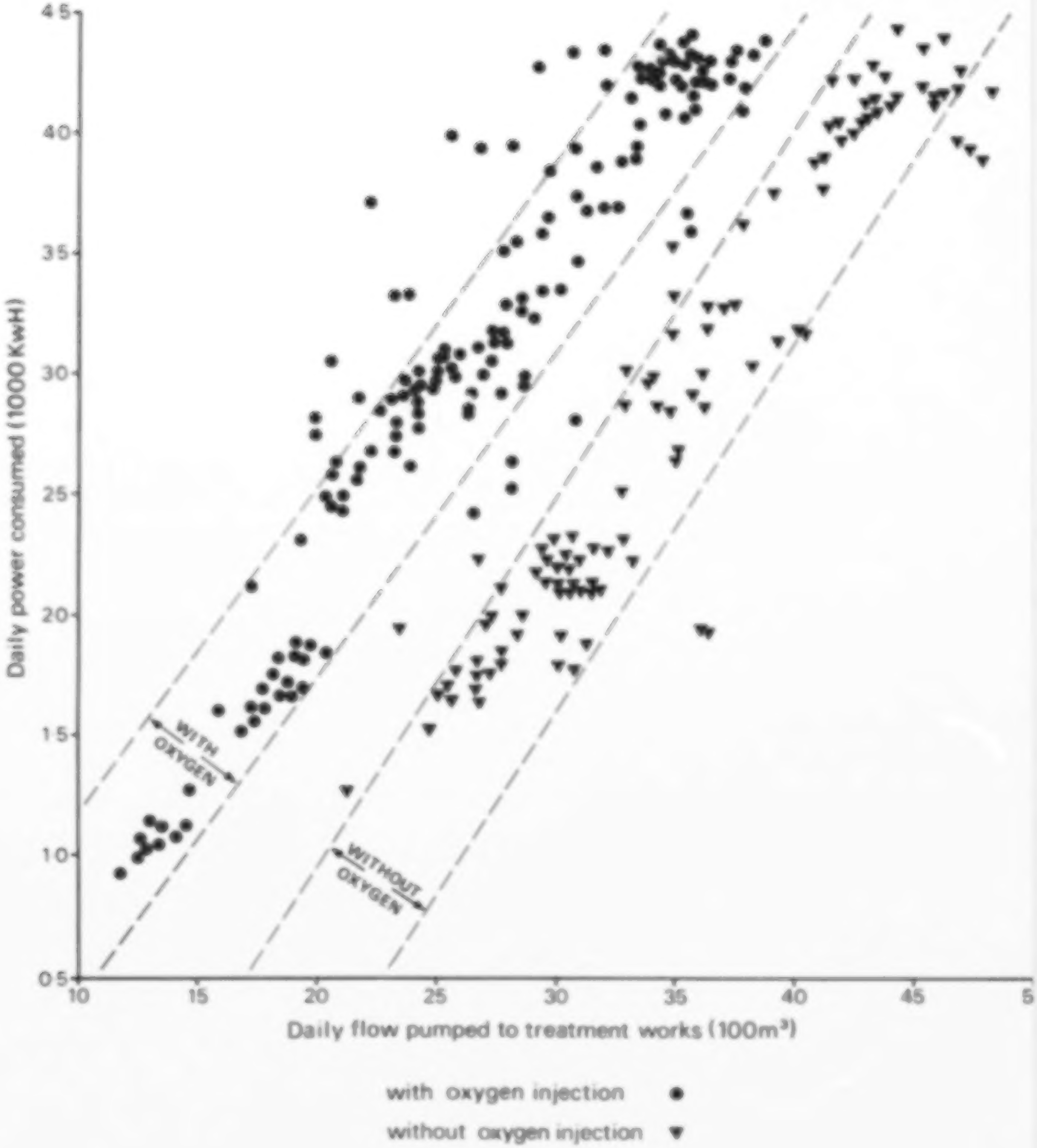
Four 15.25 m diameter radial-flow tanks, total capacity 4,570 m^3, originally designed to give 6.9 h retention and to have an upward-flow velocity of 0.9 m/h, at a dwf of 15,900 m^3/d.

		Unbracketted figures WITH oxygen injection, bracketted figures WITHOUT					
	Upward flow (u/f)	BOD$_5$			SS		
Flow 1000 m^3/d)	veloc m/h	Raw wastewater	Settled effluent	% removal	Raw wastewater	Settled effluent	% removal
> 20	1.1	205	96	53	223	69	69
> 20	1.1	(259)	(161)	(38)	(236)	(99)	(58)
20-25	1.3	199	90	55	195	62	68
20-25	1.3	(248)	(134)	(46)	(246)	(98)	(60)
25-30	1.5	157	71	55	190	60	68
25-30	1.5	(232)	(125)	(46)	(213)	(83)	(61)
30-35	1.9	136	65	62	177	67	62
30-35	1.9	(177)	(92)	(48)	(178)	(69)	(61)
35-40	2.2	104	56	46	141	55	61
35-40	2.2	(144)	(85)	(41)	(160)	(67)	(58)

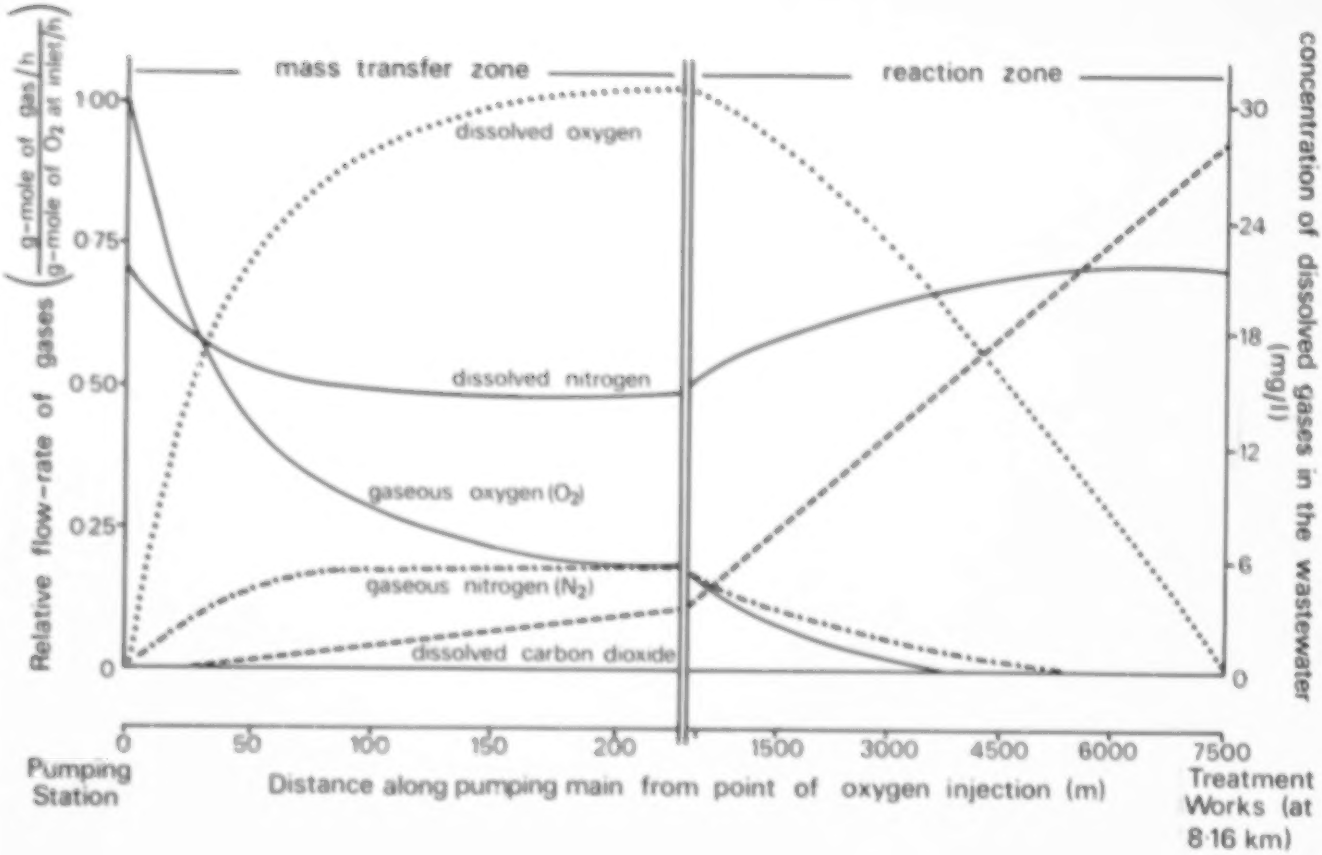
Season	Average u/f velocity m/h	Average wastewater temperature ($^\circ$C)	Unbracketted figures WITH oxygen injection, bracketted figures WITHOUT Removals in primary tanks, %	
			BOD	SS
Summer	1.5	20	62	75
Summer	1.5	(19)	(50)	(63)
Winter	1.5	10	44	61
Winter	1.5	(11)	(37)	(58)

Appendix A43

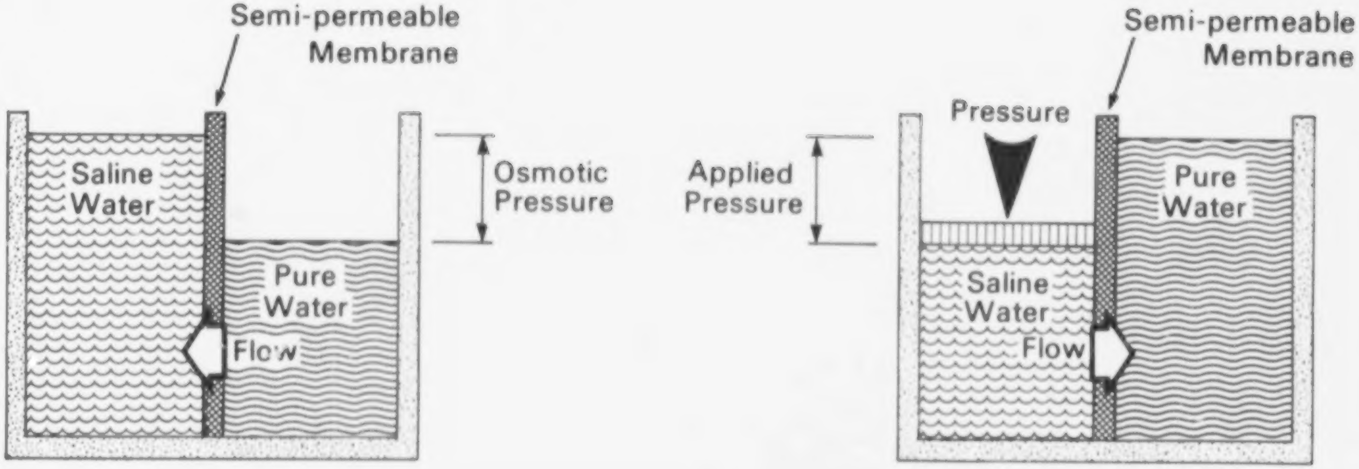
Effects on power consumption from injecting oxygen into the Bath Wastewater Pumping Main.



Presumed variations in concentrations of dissolved gases and composition of dispersed gases in the Bath Pumping Main.



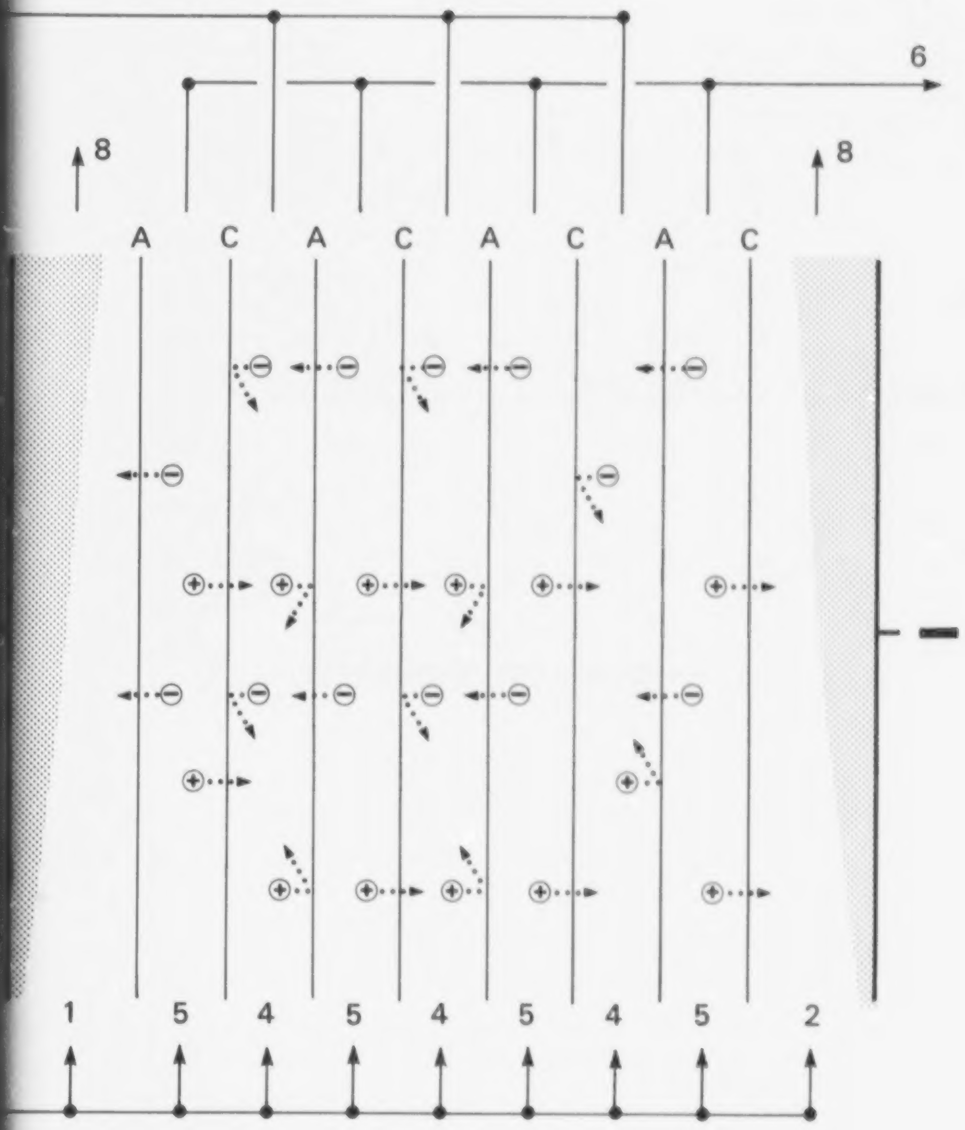
Assumed conditions of operation at Oxygen Injection Point	
Hydrostatic pressure	1·42 bar absolute
Oxygen flow-rate	50 kg/h
Wastewater velocity	0·76 m/s
Diameter of oxygen bubbles	5mm
Wastewater temperature	15° C
Oxygen consumption rate	15 mg/lh


Semi-permeable Membrane
Saline Water
Pure Water
Flow
Osmotic Pressure
Applied Pressure
Pressure
Semi-permeable Membrane
Saline Water
Flow
Pure Water

The Natural Osmosis process

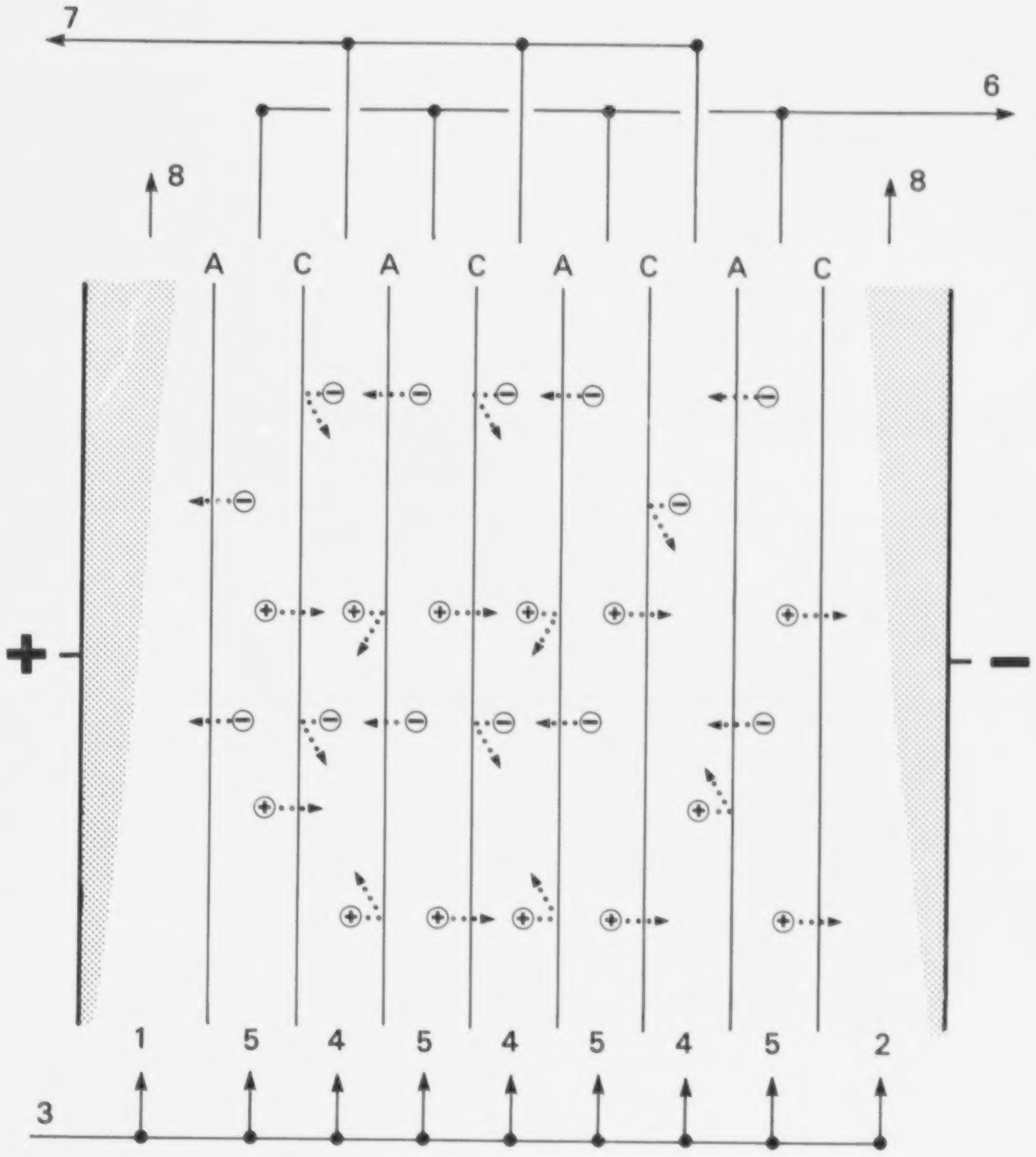
Reverse Osmosis

Simplified Representation of Natural and Reverse Osmosis Processes



Diagrammatic Representation of an Electrodialysis cell

1	Cathode compartment
2	Anode compartment
3	Water in for treatment
4	Concentrate cells
5	Product water (diluate) cells
A	Anion permeable membrane
C	Cation permeable membrane
6	Product water out
7	Concentrate out
8	Gas generation at electrodes



Diagrammatic Representation of an Electrodialysis cell

1	Cathode compartment
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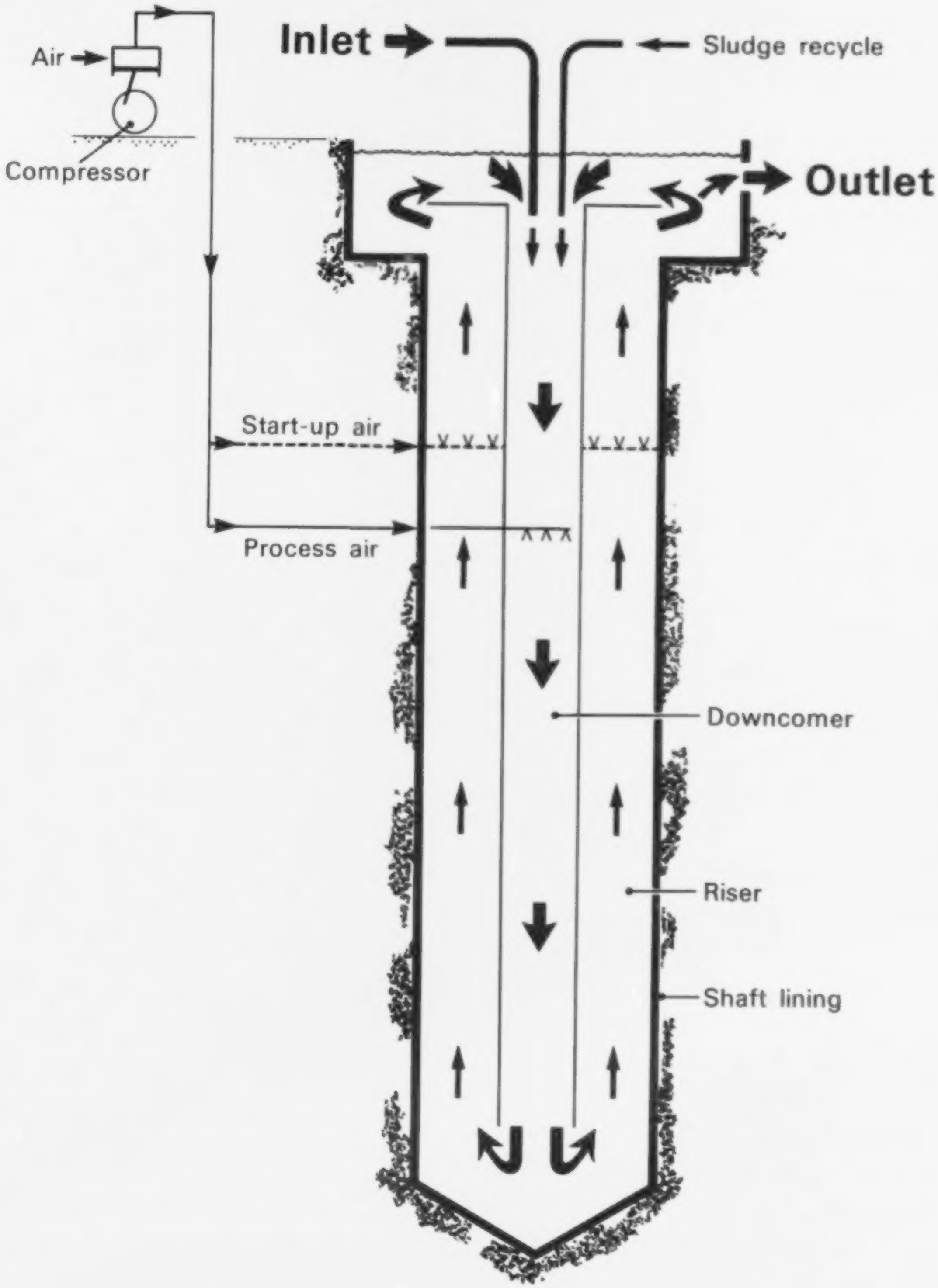
5	Product water (diluate) cells
A	Anion permeable membrane
C	Cation permeable membrane
6	Product water out
7	Concentrate out
8	Gas generation at electrodes

Appendix A47

I.C.I Deep Shaft Unit


Inlet
Sludge recycle
Air
Compressor
Outlet
Start-up air
Process air
Downcomer
Riser
Shaft lining

APPENDIX A48

Hypothetical example of the use of Discounted Cash Flows to Estimate Savings arising from the addition of Advanced Treatment Stages to an Existing Traditional Plant

1.

Capital costs of additional plant	£1000
Operating costs	£100 per annum
Additional operating costs with AWT	£50 per annum

2. The assumption of constant operating costs with increasing flows may be unrealistic but it is adopted only to simplify calculation. It is assumed that the capacity has to be increased immediately if traditional treatment is adopted but Advanced Wastewater Treatment (AWT) can facilitate postponement of new capacity for four years. The capital cost for AWT is assumed to be relatively small and is therefore considered to be zero for this exercise. Thus the cost profiles are as follows.

3. Where costs are spread over time, discounting is used to estimate all costs in terms of a common base period. A given money cost is reduced by an amount depending on its distance into the future. Thus the present value of an item of expenditure C in the year N is $\frac{C}{(1 + L)^n}$ where (100 x L) is the percentage discount rate. Prior to the publication a recent Government white paper on the nationalised industries the discount rate for the United Kingdom Public Sector was 10%. The Government is now committed to consultations on an appropriate rate of return for the water industry.

Year	Traditional Treatment		Advanced Treatment	
	Capital Cost £	Operating Cost £	Capital Cost £	Operating Cost £
0	1000	0	0	
1		100		150
2		100		150
3		100		150
4		100	1000	150

4. The introduction of new capacity in year 4 means that AWT is no longer needed and operating costs are thenceforth the same. Thus with a discount rate of 10% the capital cost discounted to year 0 of additional capacity using AWT is

$$\frac{1000}{(1+0.1)^4} = £683$$ and the discounted additional operating cost is

$$\frac{50}{1+0.1} + \frac{50}{(1+0.1)^2} + \frac{50}{(1+0.1)^3} + \frac{50}{(1+0.1)^4} = £158$$

5. Thus the total saving on capital costs is £1000-683 = £317; the additional operating costs (£158) must be offset against the saving on capital costs, thus the nett saving is £317-158 = £159.

Cost of Advanced Wastewater Treatment in co-pilot countries — Federal Republic of Germany

1. Chart No 1 shows costs per cubic metre of tank against volume of tank in increasing order of surface aeration to pressure aeration, oxygen aeration, and oxygen aeration including the costs of the production plant. This chart is not thought to be fair to oxygen treatment because it does not take into account the larger treatment capability per cubic metre of tank with oxygen.

2. Chart No 2 shows costs of construction of the production plant per ton of oxygen per day capability.

3. Aeration with oxygen was compared with that using air and appeared to be more expensive. It is thought that this disadvantage will be greatly reduced if allowance is made for the benefits resulting from the easier dewatering of sludge resulting from oxygen aeration. The sludge volume index (SVI) from oxygen plants is thought to be between 50 and 100 whereas that from aeration is rarely below 100. Munich University are examining and attempting to quantify this difference and the results of their work will be fed into the final form of the Aachen Report.

4. The estimated costs of works A to treat sewage from an equivalent population of 100,000 and of works B to treat sewage from an equivalent population of 500,000 using aeration are shown in the following table in Deutsch-marks. (1976).

	Total Construction cost DM	Construction cost per head	Capital, Maintenance and operating costs	Costs per year population equivalent
Works A				
Aeration	15,566,000	155.65	2,716,387	27.16
Oxygen aeration	15,895,000	158.95	2,805,356	28.85
Works B				
Aeration	50,396,000	100.79	9,660,197	19.32
Oxygen aeration	52,852,000	105.70	9,917,213	19.83

Chart no.1

Specific Construction Costs for Activated Sludge Tank (construction and mechanical equipment) (1977)

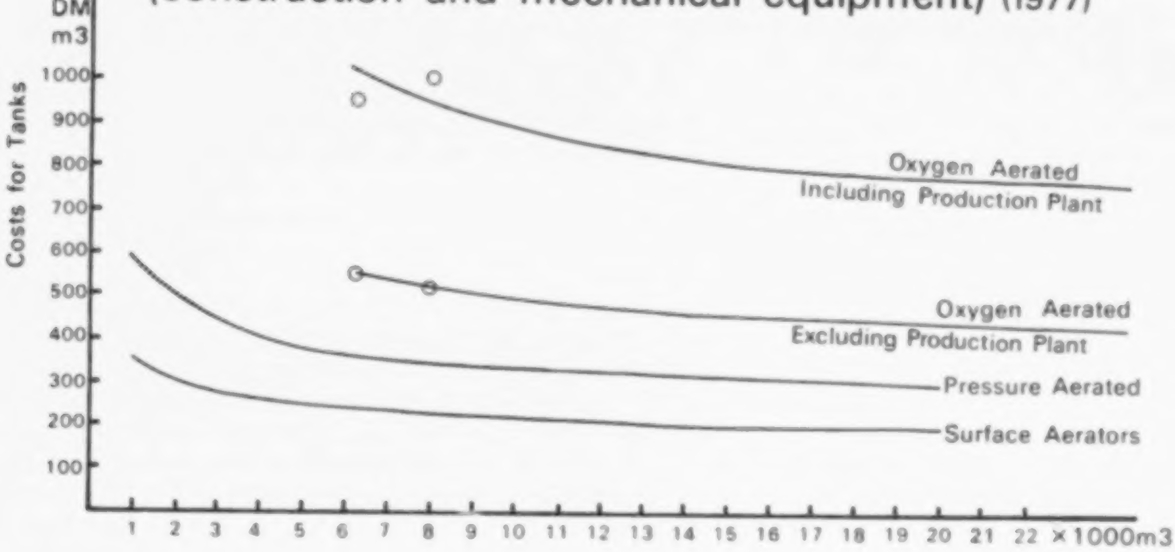
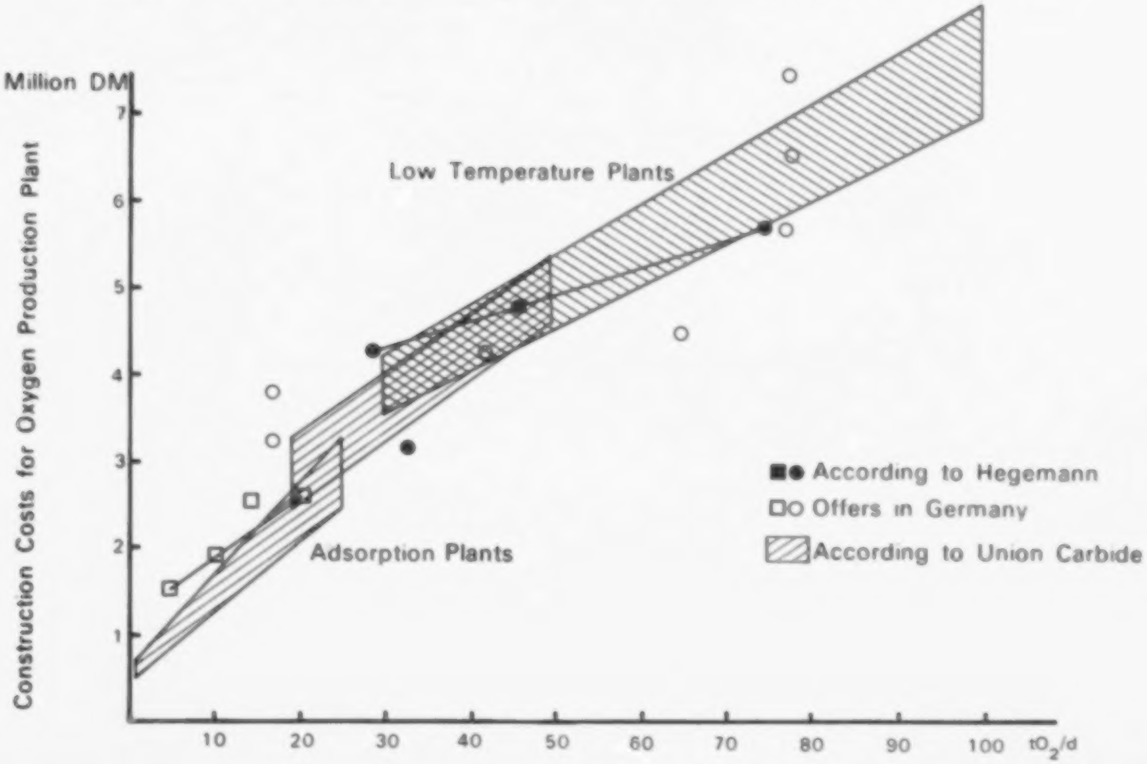


Chart no.2

Capital Costs of Oxygen Generating Plants (1977)



Cost of Advanced Wastewater Treatment in co-pilot countries — Italy

1. The attached table lists the costs (1974 prices) calculated for a reverse osmosis plant with a capacity up to 200 m^3/h. It shows that the disposal of the concentrate from the reverse osmosis treatment has a significant effect on the cost of treatment, despite the high recovery factors reached. However, in Italy, the cost is still competitive with that of any alternative biological processes. The results obtained require experimental confirmation from long-term testing in a multi-module plant, especially to evaluate the behaviour and life of the membranes installed on modules operating at high recovery factors.

2. Parallel experiments should be carried out to find an alternative pre-treatment or disposal of the concentrate since the cost of incineration is considered a sensible part of the total treatment cost.

3. Treatment tables list the cost components referring to complete treatment of the effluent by reverse osmosis.

4. Evaluation of the plant costs and of module replacement is based on quotations supplied by the manufacturers. For ammortisation, a period of 10 years at an interest of 10% was assumed. The average life of the membranes was estimated to be three years but requires experimental verification by long term tests.

5. For the incineration of the last concentrate, a cost of 5000 lire/m^3 was assumed. Operating at a recovery factor of 97%, it was calculated that the cost of complete treatment is about 410 lire/m^3 using a reverse osmosis plant with Du Pont or Gulf General Atomic (now UOP) modules and 620 lire m^3 using UOP tubular modules. The influence of incineration on the treatment costs is very high: 37% and 24% of the respective total costs.

Treatment costs (1974 prices) for a reverse osmosis plant (UOP modules) treating up to 100 m^3/h of effluent from a fibre finishing plant

---

Operating costs (lire/m^3):	
Chemicals	5
Electric energy (12 lire/kWh)	30
Manpower and maintenance (1) (3 persons at 8 million lire/y)	75
Modules replacement (mean life: three years)	40
Activated carbon (regeneration + replacement)	20
General costs	20
Incineration of the concentrate	70
Total operating costs (lire/m^3)	260
Capital costs (lire/m^3):	
Ammortisation + interest (10% for 10 years)	210
Total treatment costs (lire/m^3)	470

(1) Part of the personnel's time is occupied in shifts on the production line.

Treatment costs (1974 prices) for three reverse osmosis plants treating up to 200 m^3/h of effluent from an acrylic fibre manufacturing plant are as follows:

Plant	GGA*	Du Pont	UOP
Operating costs (lire/m^3):			
Chemicals	15	15	15
Electric energy (12 lire/kWh)	25	18	25
Manpower and maintenance	57	57	57
Modules replacement (mean life: 3 years)	43	57	157
General costs	20	20	20
Incineration of the concentrate	150	150	150
Total operating costs (lire/m^3)	310	317	424
Capital costs (lire/m^3):			
Ammortisation + interest	93	93	197
Total treatment costs (lire/m^3)	403	410	621

*Gulf General Atomic.

Cost of Advanced Wastewater Treatment in co-pilot countries — Norway

1. Total construction costs of advanced wastewater treatment plant in Norway are based on a survey carried out by the Norwegian Institute for Water Research (NIVA) in June 1974 of seventeen different primary and secondary precipitation plants serving populations from 1,750 to 60,000.

2. Figure 1 is a graph of the total construction cost of advanced wastewater treatment plants against the populations served. Figure 2 is a graph of the correlation between plant size (basins and service building) and total construction costs.

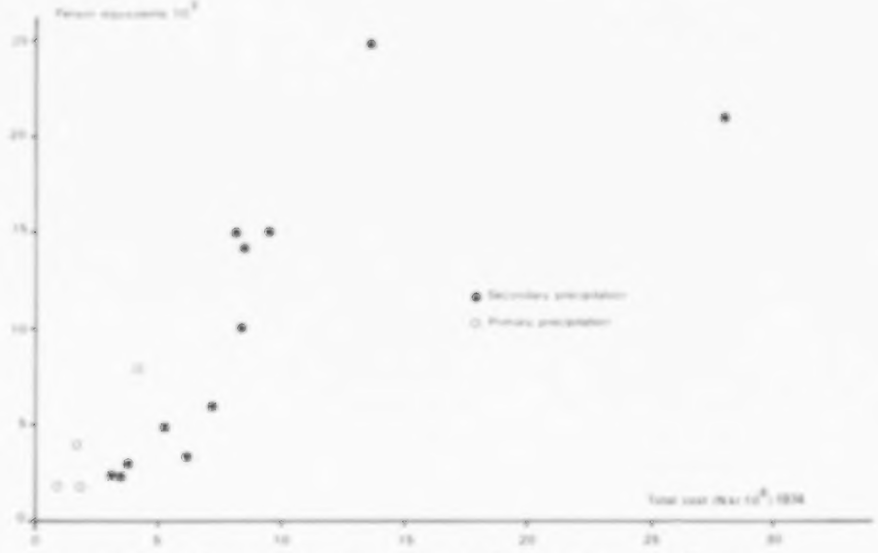


Figure 1. Total Cost vs Number of People Connected to the Plant

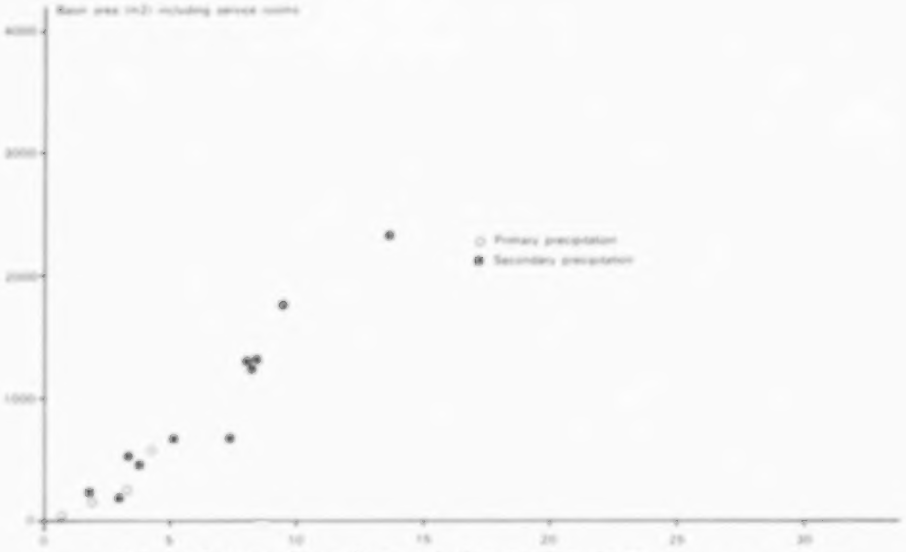


Figure 2 Total Cost vs Basin Area including service rooms

Cost of A.W.T. in Norway

Cost of Advanced Wastewater Treatment in co-pilot countries — United States

1. In examining costs for wastewater treatment processes, the United States Environmental Protection Agency, concluded that they would have little meaning to other countries unless they were carried out on a properly comparative basis. Costs were examined for three different size plants. They were 3.77tcmd (1 mgd), 37.7 tcmd (10 mgd), 377tcmd (100 mgd). From the tables it was possible to compare the cost of physical-chemical unit processes with primary sedimentation and activated-sludge. These cost tables did not include oxygen activated-sludge. The cost data at present available was obtained from Batavia, New York. Since the data is rather old, the USEPA has let a contract with a consulting firm to prepare a comprehensive design evaluation and cost comparison report for major suspended growth biological processes including submerged aeration, air activated-sludge, surface aeration, air-activated-sludge, cover reactor oxygen-activated sludge and uncovered reactor oxygen activated-sludge. This report is due to be completed in July 1978. The attached table gives United States national average cost estimates for wastewater treatment for a design capacity of 4,380 l/sec (January 1977).

(Design capacity 4380l/sec.) Processes Used	Construction Cost millions of dollars	Level Debt Service cents/10m3 25yr. 6%	operating and maintenance cents/10m3	Total Treatment Cost cents/10m3	Estimated Contaminant Removal Percent								
					5-day BOD* COD**	35*	88*	95*	97*	97*	97*	98**	98**
					Phosphorus	10	25	35	92	92	92	95	98
					Nitrogen	0	0	0	0	0	85	85	85
Primary Sedimentation and Sludge Disposal	54·3	30·6	27·6	112·5		▨							
Primary Activated Sludge and Sludge Disposal	122·0	69·7	40·4	232·1			▨	▨	▨	▨	▨	▨	▨
Microscreening	10·9	5·8	6·2	22·9				▨					
Single Stage Lime Clarification	26·6	15·3	32·8	74·7					▨		▨	▨	
Two Stage Lime Clarification	38·1	22·2	42·7	103·0						▨			▨
Ammonia Stripping and Recarbonation (summer only)	33·0	18·0	21·4	72·4							▨	▨	▨
Multi-media Filtration	11·2	6·9	11·4	29·5								▨	▨
Granular Carbon Adsorption 40 min. contact	64·4	36·4	57·5	158·3								▨	▨
Chlorination 8mg/l	1·6	1·4	3·8	6·8			▨	▨	▨	▨	▨	▨	▨
Total Treatment Cost cents/10m3 influent						112·5	238·9	261·8	313·6	341·9	386·0	573·8	602·1

Cost Estimates for Wastewater Treatment National Average January 1977

(Design capacity 4380l/sec.) Processes Used	Construction Cost millions of dollars	Level Debt Service cents/10m3 25yr. 6%	operating and maintenance cents/10m3	Total Treatment Cost cents/10m3	Estimated Contaminant Removal Percent							
					5-day BOD* COD**	35*	88*	95*	97*	97*	97*	98**
					Phosphorus	10	25	35	92	92	92	95
					Nitrogen	0	0	0	0	0	85	85
Primary Sedimentation and Sludge Disposal	54·3	30·6	27·6	112·5		▨						
Primary Activated Sludge and Sludge Disposal	122·0	69·7	40·4	232·1			▨	▨	▨	▨	▨	▨
Microscreening	10·9	5·8	6·2	22·9				▨				
Single Stage Lime Clarification	26·6	15·3	32·8	74·7					▨		▨	▨
Two Stage Lime Clarification	38·1	22·2	42·7	103·0						▨		
Ammonia Stripping and Recarbonation (summer only)	33·0	18·0	21·4	72·4							▨	▨
Multi-media Filtration	11·2	6·9	11·4	29·5								▨
Granular Carbon Adsorption 40 min. contact	64·4	36·4	57·5	158·3								▨
Chlorination 8mg/l	1·6	1·4	3·8	6·8			▨	▨	▨	▨	▨	▨
Total Treatment Cost cents/10m3 influent						112·5	238·9	261·8	313·6	341·9	386·0	573·8

US Cost Estimates for Wastewater Treatment National Average January 1977

APPENDIX A50

Estimated Granular Activated Carbon Treatment Costs* (USA) (March 1975)

Capital Costs (1000 of $)

Influent pumping	219		
Initial carbon charge	331		
Carbon contacting system	1,766		
Carbon regeneration system	650		
Total	2,966		
Engineering, legal and administrative costs (20%)	593		
Total capital cost	3,559		
Amortized cost, ¢/m^3 (¢1000 gallons)		2.04	(7.62)

Operating and Maintenance Costs ¢/m^3 (¢/1000 gallons)

Carbon make-up	0.16	(0.62)
Backwash water	0.04	(0.15)
Power and fuel	0.24	(0.89)
Sulfide control (sodium nitrate)	0.51	(1.93)
Operating and maintenance labor	0.34	(1.28)
Maintenance material	0.07	(0.27)
Total operating and maintenance cost, ¢/m^3 (¢/1000 gallons)	1.36	(5.14)
Total treatment cost, ¢/m^3 (¢/1000 gallons)	3.40	(12.76)

*Based on EPA sewage treatment plant construction cost index of 232.1 (March 1975) for a 37,850 cu m/day (10 mgd) plant.

ESTIMATED POWDERED CARBON TREATMENT COSTS (JULY 1973) (USA)

APPENDIX A51

Regeneration and Reuse	YES				NO			
Plant Flow, km³/d (mgd)	38	(10)			38	(10)		
Carbon Dosage, mg/l	100		300		100		300	
Capital Costs (1000 of $)								
Carbon Treatment		997				997		
Granular Media Filtration		580				580		
Gravity Thickening	60		97		60		97	
Vacuum Filtration	170		270		170		270	
Thermal Regeneration	800		1600		–		–	
Total	2607		3544		1807		1944	
Contingency (50%)	1304		1772		904		972	
Capital Costs								
Total	3911		5316		2711		2916	
Amortized Cost[a] ¢/m³ (¢/1000 gal)	2.2	(8.4)	3.0	(11.4)	1.5	(5.8)	1.7	(6.3)
Operating Costs ¢/m³ (¢/1000 gal)								
Carbon Makeup	0.21[b]	(0.8[b])	0.66[b]	(2.5[b])	2.11[c]	(8.0[c])	6.34[c]	(24.0[c])
Regeneration (Fuel, Power, Labour)	0.39	(1.5)	0.90	(3.4)		–		–
Power	0.05	(0.2)	0.05	(0.2)	0.05	(0.2)	0.05	(0.2)
Supervision & Labour	0.66	(2.5)	0.66	(2.5)	0.66	(2.5)	0.66	(2.5)
Maintenance, @ 1%/Cap/Yr	0.29	(1.1)	0.40	(1.5)	0.21	(0.8)	0.24	(0.9)
Total ¢/m³ (¢/1000 gal) Operation	1.6	(6.1)	2.7	(10.1)	3.0	(11.5)	7.3	(27.6)
Total Treatment Costs	14.5		21.5		17.3		33.9	
¢/1000 gal (¢/m³)	(3.8)		(5.7)		(4.6)		(9.0)	

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[a] 25 years @ 6%

[b] 10% Makeup

[c] 100% Makeup

COST OF MULTIHEARTH REGENERATION (MAY 1975) (USA) APPENDIX A52

	Regeneration rates or capacities (lb./day)						
Operating Costs, $/lb.	125	500	2,000	3,000	7,000	16,000	70,000
	Operating costs common to industrial & municipal systems						
Utilities							
Steam @ $1.4/1,000lb	0.00084	0.00084	0.00084	0.00084	0.00084	0.00084	0.00084
Electricity @ $0,015/kWh	0.00117	0.00078	0.00069	0.00052	0.00030	0.00016	0.00006
No. 2 Fuel Oil @ $0.35/gal. @ 141,000 B.T.U./gal)	0.02085	0.01464	0.01291	0.01241	0.01167	0.01067	0.00918
Subtotal	0.02286	0.01626	0.01444	0.01377	0.01281	0.01167	0.01008
Operating labor (OL) (@$5.00/hr.)	0.09300	0.04450	0.03000	0.02000	0.00850	0.00375	0.00085
Carbon Makeup @ $0.34/lb.†	0.03400	0.03400	0.02380	0.02380	0.01960	0.01960	0.01960
Maintenance Labor & Materials (MLM) (@ 50% (FI)/yr.)	0.22400	0.05600	0.01000	0.00776	0.00771	0.00455	0.00204
Subtotal	0.35100	0.13450	0.06380	0.05156	0.03581	0.02790	0.02249
Totals	0.37386	0.15076	0.07824	0.06533	0.04862	0.03957	0.03257
	Other operating costs for municipal systems						
Operating Supplies @ 10% (MLM)	0.02240	0.00560	0.00100	0.00078	0.00077	0.00045	0.00020
Overhead, Laboratory & Supervision @ 45% (OL) + 25% (MLM)	0.09785	0.03402	0.01600	0.01094	0.00575	0.00283	0.00089
Amortization @ 10.2% (FI)/yr.	0.32640	0.08160	0.02040	0.01583	0.01574	0.00929	0.00416
Insurance @ 1% (FI)/yr.	0.03200	0.00800	0.00200	0.00155	0.00154	0.00091	0.00041
Total	0.47865	0.12922	0.03940	0.02910	0.02380	0.01348	0.00566
Grand Totals	0.85251	0.27998	0.11764	0.09443	0.07242	0.05305	0.03823
	Other operating costs for industrial systems						
Operating Supplies @ 4% (OL)	0.00372	0.00178	0.00120	0.00080	0.00034	0.00015	0.00003
Overhead, Laboratory & Supervision @ 105% (OL)	0.09765	0.04672	0.03150	0.02100	0.00892	0.00394	0.00089
Depreciation @ 9.1% (FI)/yr.	0.29120	0.07280	0.01820	0.01413	0.01404	0.00614	0.00371
Plant Insurance and Local Taxes @ 0.5% (FI)/yr.	0.01600	0.00400	0.00100	0.00076	0.00076	0.00033	0.00020
Total	0.40857	0.12530	0.05190	0.03669	0.02406	0.01056	0.00483
Grand Total	0.78243	0.27606	0.13014	0.10202	0.07268	0.05013	0.03740

---

† $0.28/lb. at greater than 6,000 lb./day, because makeup work probably would be purchased in carload or bulk shipments.

CONVERSION TO METRIC UNITS.

To convert 1lb/day to kg/d	x by 0.454
To convert $/lb to $/kg	x 2.205
To convert $/gall to $/m^3	x by 264.5
To convert BTU/gal to kJ/m^3	x by 278.7

EFFECT OF CARBON COST AND MAKEUP REQUIREMENTS ON MULTIHEARTH REGENERATION. (INDUSTRIAL PARAMETERS) (USA)

APPENDIX A53

	Regeneration rates or capacities (lb./day)						
Operating Costs, $/lb.(May 1975)	125	500	2,000	3,000	7,000	16,000	70,000
Costs other than carbon costs	0.74843	0.24206	0.10634	0.07822	0.05308	0.03053	0.01780
Carbon Costs @ 7% makeup @ $0.34/lb.	0.03400	0.03400	0.02380	0.02380	0.01960	0.01960	0.01960
(Base Case) Total Operating Cost	0.78243	0.27606	0.13014	0.10202	0.07268	0.05013	0.03740
7% Makeup – $0.40/lb	0.0400	0.04000	0.02800	0.02800	0.02380	0.02380	0.02380
Total Operating Cost	0.78843	0.28206	0.13434	0.10622	0.07688	0.05433	0.04160
% Increase Over Base	0.8	2.1	3.2	4.1	5.8	8.4	11.2
10% Makeup – $0.34/lb	0.04760	0.04760	0.03400	0.03400	0.02800	0.02800	0.02800
Total Operating Cost	0.79603	0.28966	0.13434	0.11222	0.08108	0.05853	0.04580
% Increase Over Base	1.7	4.9	7.8	10.0	11.6	16.8	22.5
10% Makeup – $0.40/lb	0.05600	0.05600	0.04000	0.04000	0.03400	0.03400	0.03400
Total Operating Cost	0.80443	0.29906	0.14634	0.11822	0.08708	0.06453	0.05180
% Increase Over Base	2.8	8.0	12.4	15.9	19.8	28.7	38.5

Makeup 10% for intermittent operation at 7% for continuous operation, or 14% for continuous operation. From Table 4.

CONVERSION TO METRIC UNITS

To convert 1lb/day to kg/d	x by 0.454
To convert $/lb to $/kg	x by 2.205
To convert $/gal to $/m^3	x by 264.5

ESTIMATED POWDERED CARBON REGENERATION COSTS (1974) (USA)

APPENDIX A54

Carbon Dosage, mg/l	75		300	
Assumed Regeneration Losses, %	Total Regeneration Costs ¢/kg (¢/lb) of PAC used			
0	4.6	(2.1)	2.6	(1.2)
5	5.7	(2.6)	4.0	(1.8)
10	6.6	(3.0)	5.1	(2.3)
20	8.8	(4.0)	7.3	(3.3)
30	11.0	(5.0)	9.7	(4.4)
40	13.0	(5.9)	11.9	(5.4)

Plant Details

APPENDIX B1

APPENDIX NO.		TITLE
B1		FRANCE
	B1/1	France 1 — Calavon.
	B1/2	France 2 — Chantilly.
	B1/3	France 3 — Cons-la-Granville
	B1/4	France 4 — Coutras Distillery
	B1/5	France 5 — Dunkerque — Grande Synthe.
	B1/6	France 6 — Etans de Berre, Lavera, Marseille.
	B1/7	France 7 — Fouesnant Beg Meil.
	B1/8	France 8 — Fougéres.
	B1/9	France 9 — Olonzac.
	B1/10	France 10 — Nice-Ferber.
	B1/11	France 11 — Talmont Saint Hilaire.

1. France — Calavon

1.1. This plant, which treats distillery wastes at Calavon, uses physical-chemical techniques to neutralise the acidity, flotation for concentration of solids, and a belt press for sludge dewatering.

1.2. The plant is capable of treating the waste from the daily production of 12,000 litres of pure alcohol, that is an effluent containing 10 tonnes of suspended solids, 12 tonnes of COD and 5 tonnes of BOD per day. The effluent is evaporated on a 5 hectare site and since the soil is alkaline and the effluent acidic the product is neutral and useful.

CALAVON — Automatic Dosing Plant and Flotation Unit.

2. France — Chantilly

2.1. The object of the pilot plant at Chantilly is similar to that at Fougères in that it is aimed at optimising the reduction of the high ammoniacal nitrogen. One tank has been used with periods of aeration to nitrify and denitrify and has given 85% elimination of nitrogen. Since pollution is in the ammoniacal form it is essential to nitrify and denitrify using very fine limits.

3. France — Cons-La-Granville

3.1. The dairy at Cons-la-Granville has a capacity to treat 120,000 litres of milk per day. It comprises a pasteurization and plastic-bottling line, a butter and fresh cream production unit and a casein factory which operates when the milk delivered to the dairy exceeds requirements.

3.2. When the casin factory is not in operation the waste has the following characteristics: —

average pH	6.5-8 with peaks of 10.2 and 4.5
temperature	11° to 40°C with variations of 10° C in several hours
suspended solids	80 to 350 mg/l after grease removal
COD	from 250 to 1000 mg/l as a daily average
COD/BOD_5	1.5 to 1.6

When casein is produced the average CODs increase and vary between 1500 and 2500 mg/l with peaks over 24 hours of up to 3500 mg/l.

3.3. The pilot installation includes a line for purification with air and a line for purification with oxygen so that the processes may be compared.

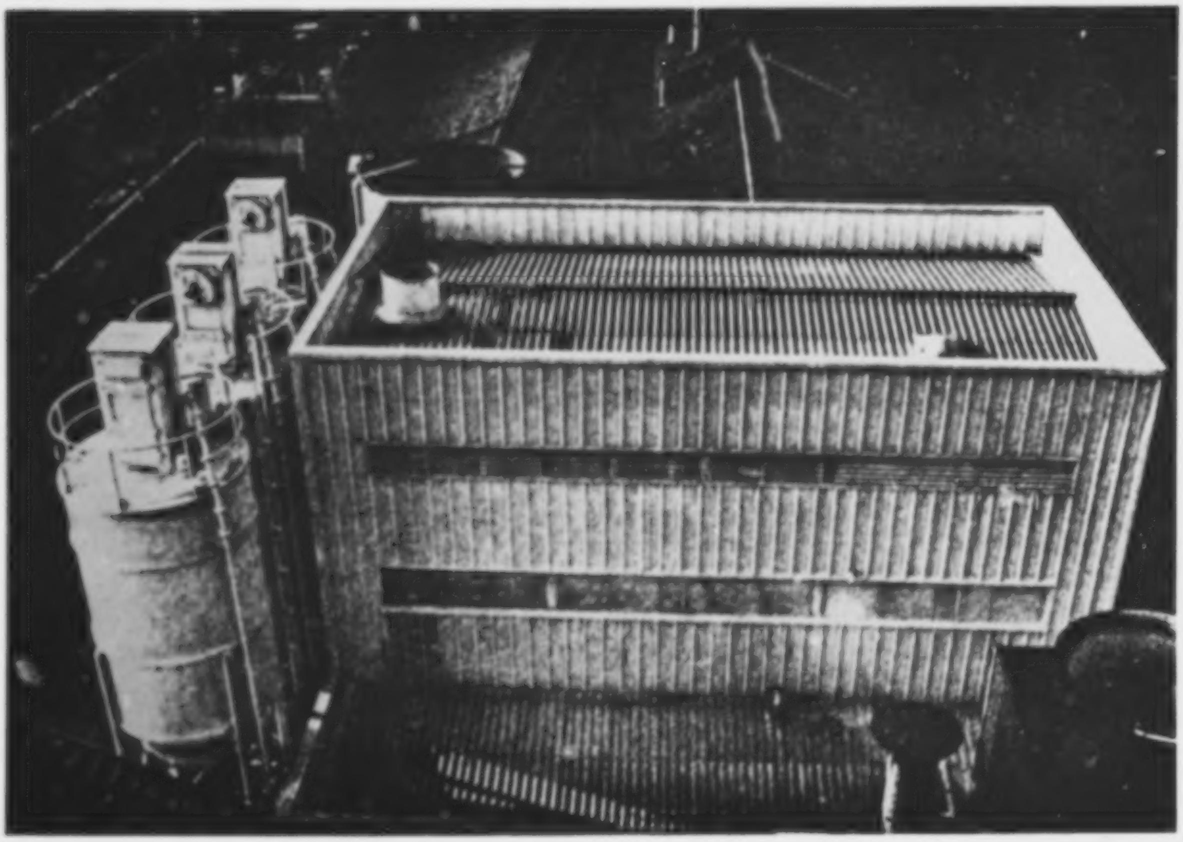
3.4. The pilot plant for purification with oxygen comprises a closed activated tank with a liquid capacity of 6.5 m^3 which can be separated into 3 equal chambers with a gaseous layer 0.8 m deep above. The tank is followed by a settling tank 3.8 m^2 in area or flotation using a pressure unit with a surface area of 2.5 m^2.

3.5. The pilot plant for purification with air consists of 2 cylindrical activation tanks which have a total capacity of 3.8 m^3 of effluent and can be fed in series or in parallel. The treated effluent is separated in a 3.4 m^2 area clarifier.

3.6. Both pilot plants were equipped with facilities for recycling with a variable speed screw pump. Initially liquid-solid separation for the oxygen line was by clarification but it has been switched to flotation. Various combinations of the three tanks were used.

4. France — Coutras Distillery

4.1. The purification plant was designed to treat 8 m^3 of very weak wine per hour. Suspended matter is separated by two centrifugations followed by precipitation of the tartaric acid and concentration of the liquors in a triple effect evaporator. Precipitation is effected by alum and lime. The evaporator uses about 0.4 kg of vapour per kg of water evaporated.



COUTRAS — Distillery Waste Treatment Plant.

5. France — Dunkerque Grande Synthe

5.1. The area has a separate system of sewerage and drains to a plant designed to treat 9000 m^3/day of sewage from 45,000 persons. The mean flow is 375 m^3/hour with a peak flow of 900 m^3/hour. The BOD_5 of the sewage is 3150 kg/day or 350 mg/l.

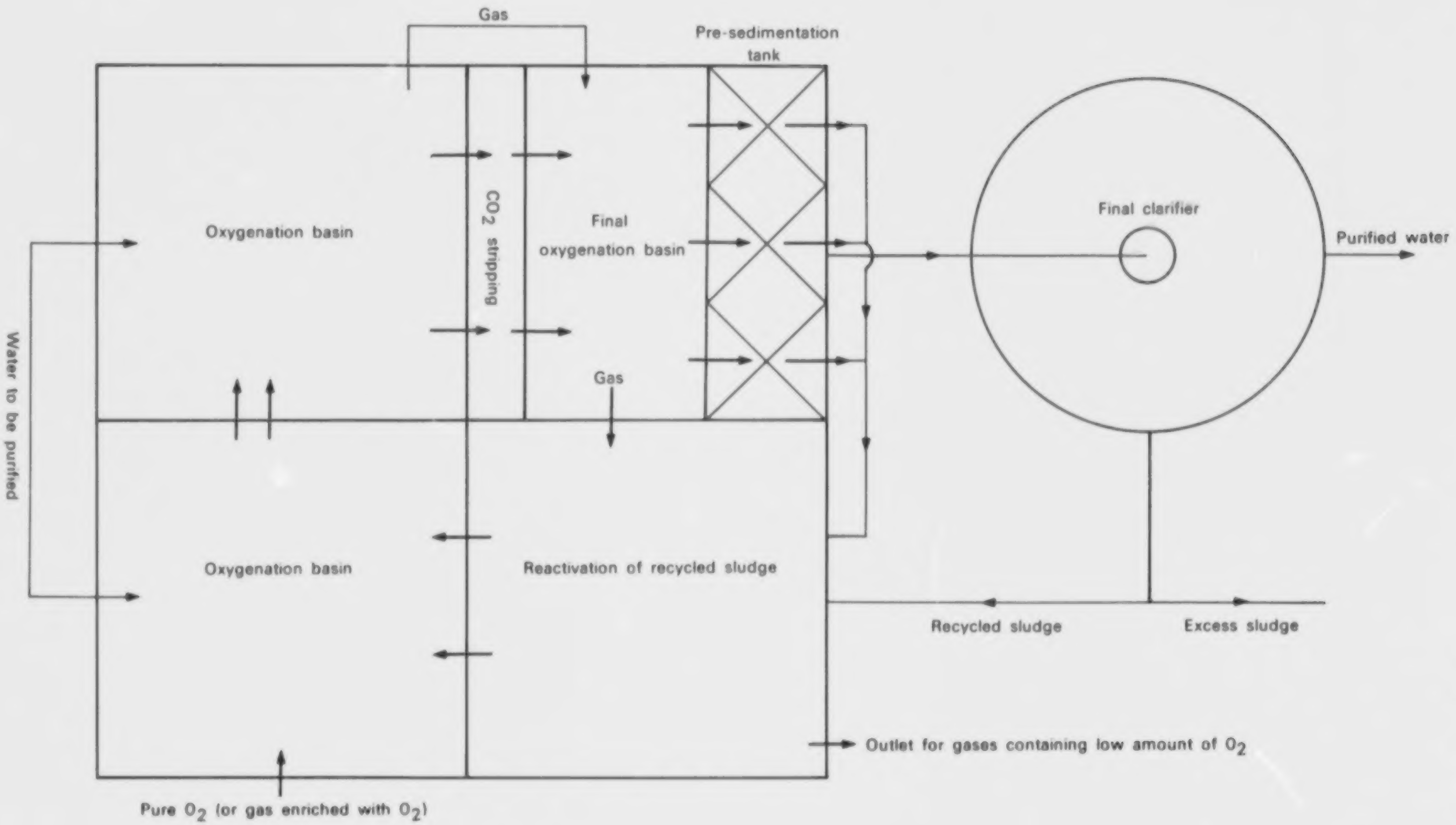
5.2. Sewage is screened and degritted before it is treated by activated sludge using oxygen in a covered 4-cell basin. In the first 2 cells there is contact between the activated-sludge and the sewage, in the third the sludge is separated and in the fourth cell the sludge is re-activated. Oxygen is introduced into the contact basins by surface aerators. In the third cell, carbon dioxide stripping is followed by injection of oxygen rich gas, the sludge settles in a sedimentation compartment. The effluent is separated in a sedimentation tank.

5.3. Sludge is stabilised, thickened and dehydrated on centrifuges before thermal drying.

5.4. The aeration tank has a volume of 1200 m^3 and an area of 1200m^2. The clarifier has an area of 530 m^2.

5.5. The plant was designed to remove 2900 kg/day of BOD_5, equivalent to 91.4% removal, and have a loading of 2.64 kg BOD_5/m^3. It was planned to consume 3.5 tonnes of oxygen per day and produce around 2 tonnes of sludge as dry solids.

Oxygen Treatment Plant at Dunkerque


Gas
Pre-sedimentation tank
Oxygenation basin
CO_2 stripping
Final oxygenation basin
Final clarifier
Purified water
Gas
Water to be purified
Oxygenation basin
Reactivation of recycled sludge
Recycled sludge
Excess sludge
Outlet for gases containing low amount of O_2
Pure O_2 (or gas enriched with O_2)

6. France — Etans De Berre, Lavera, Marseille

6.1. This plant, operated by Naphtachimie, serves three large industrial works including a petro-chemical refinery. Effluent from the works is strong and sometimes has a temperature of 75°C. The works were designed to treat 915m^3/d in dry weather and 1200 m^3/d in wet weather containing 22,500 kg of BOD_5 and 30,000 kg of COD per day from organic matter and 1600 kg of mineral COD per day. In addition it has the ability to cool 500 m^3 of effluent from 75°C to 35°C.

6.2. After grit removal and neutralisation the effluent is cooled when necessary and pumped towards the biological treatment plant. The latter comprises two biological tanks with surface aerators, two secondary settling tanks and a sludge recovery well. Phosphoric acid and ammonia are injected into the biological tanks.

6.3 The sludge is flocculated in each of three troughs, which are stirred, in the first it is mixed with ferric chloride and in the second with lime. The sludge is pumped to filter presses before disposal.

6.4. The plant is designed to reduce COD to 6000 kg/d, a reduction of 80%, to reduce BOD_5 to 200 kg/d, a reduction of 95%, and suspended solids to less than 30 mg/l.

7. France — Fouesnant Beg Meil

7.1. The plant was designed on the following basis:

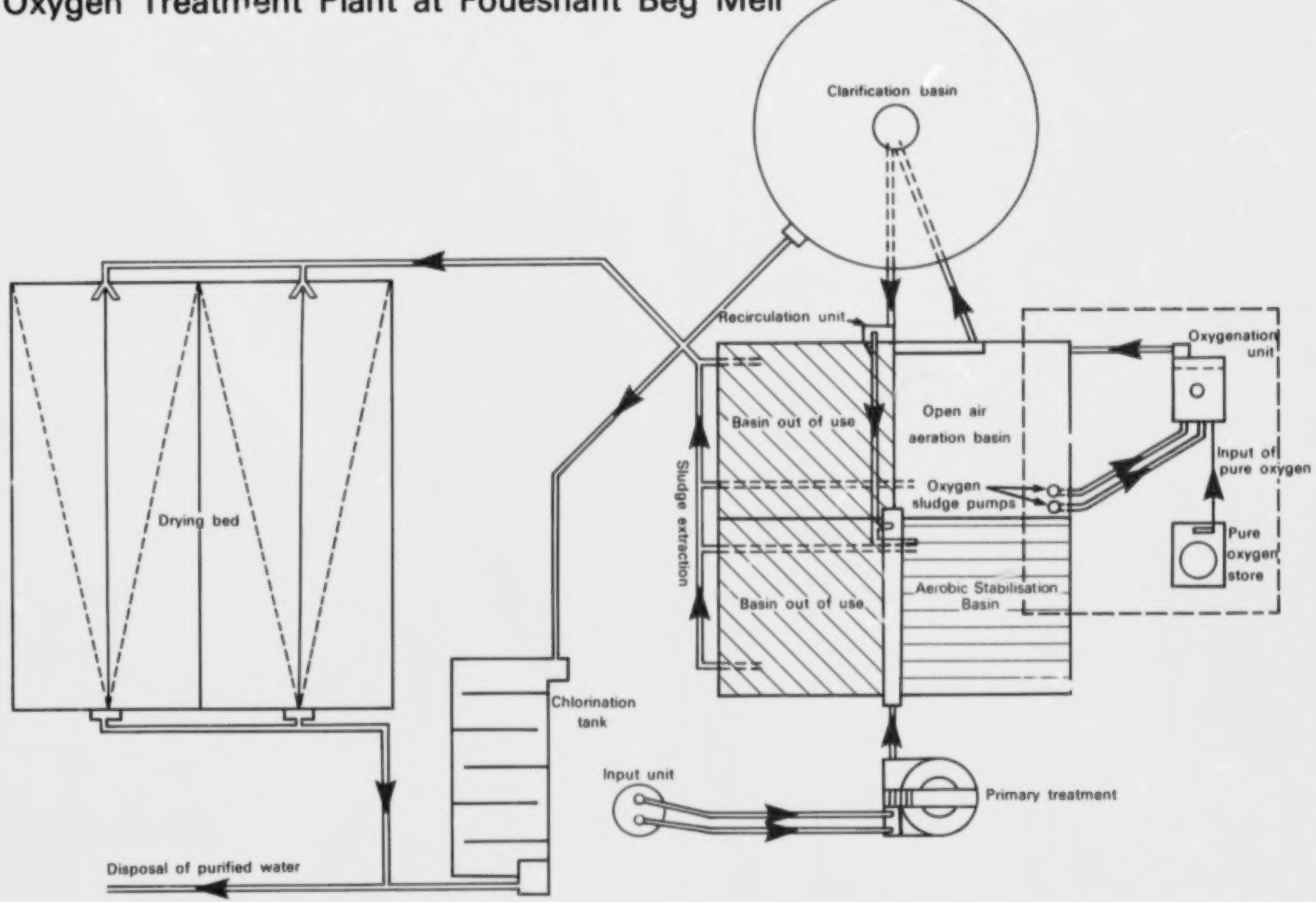
		Winter	Summer
Inhabitants		500	11,000
Sewage flow	m^3/d	50	900
Peak flow	m^3/h	6.24	86
Average flow	m^3/h	2.08	37.5
BOD	kg/d	30	660
Suspended solids	kg/d	45	990

7.2. After screening and grit removal the sewage is passed to 4 surface aeration tanks each with a volme of 471 m^3, an area of 132.25 m^2 and a liquid depth of 3.65 m. Each tank has a surface aerator capable of supplying 22.5 kg oxygen per hour. Activated sludge is drawn-off and clarified in a circular tank, which has an area of 113 m^2 and volume of 248 m^3 before it is recirculated to the aeration tanks.

7.3. The oxygenation unit consists of a 30 m^3 tank with a surface aerator capable of supplying 13 kg oxygen per hour. Activated sludge is circulated to the oxygenation unit and returned to one of the aeration tanks.

7.4. The oxygenation unit is only used during the summer season. When operated, only two of the aeration tanks are used, one to receive the oxygenated sludge and the other for the aerobic stabilisation of the excess sludge. The surface aerator may be used at the same time.

Pure Oxygen Treatment Plant at Fouesnant Beg Meil


Clarification basin
Recirculation unit
Basin out of use
Open air aeration basin
Oxygen sludge pumps
Oxygenation unit
Input of pure oxygen
Pure oxygen store
Sludge extraction
Basin out of use
Aerobic Stabilisation Basin
Drying bed
Chlorination tank
Input unit
Primary treatment
Disposal of purified water

8. France — Fougères

8.1. This pilot plant consisted of primary settlement followed by two parallel streams, one for activated sludge treatment, the other for biological filtration, the object being to determine the best system and rates for nitrification and denitrification. In the activated sludge process the rate was optimised by regulating aeration and in the biological filters by adding methanol to denitrify, or by recycling sludges.

8.2. The activated sludge process of anaerobic followed by aerobic treatment and settlement of effluent was found to be the best method of reducing nitrogen. The anaerobic tank (2 m^3) comprised 22% of the total volume and aerobic tank (7 m^3) comprised 78%. Some 150 to 200% of the complementary sludge was drawn from the aerobic tank and recycled through the aerobic and aerobic tanks as was 100% of the returned activated sludge. The flow through the pilot plant was 0.5 m^3/h.

8.3. If the load was 0.12 to 0.15 kg BOD_5 per kg suspended solids per day the effluent could be improved as follows:

	Entry	Discharge
COD	650 mg/l	70 – 80 mg/l
$N\text{-}NH_4$	65 mg/l	1 – 3 mg/l
$N - NO_3$		8 – 10 mg/l
NTK	85 mg/l	4 – 7 mg/l

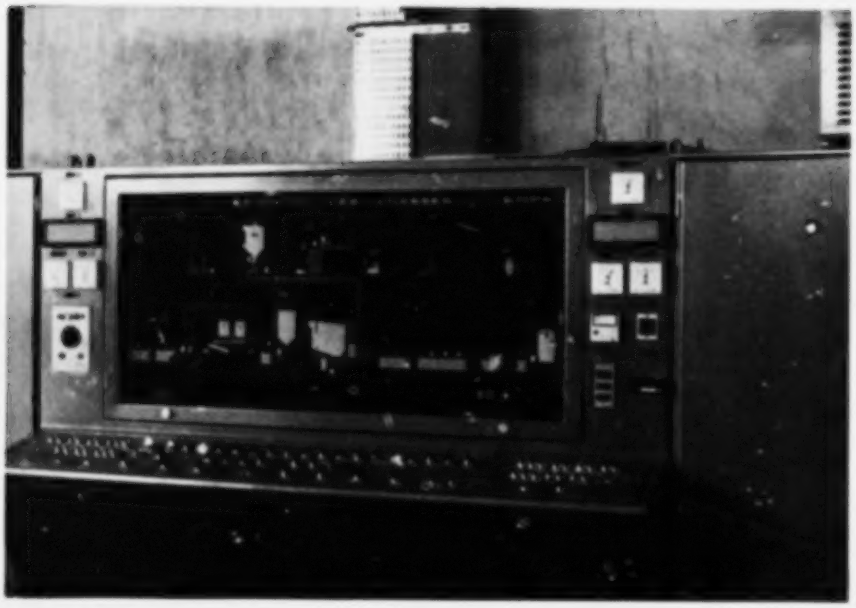
8.4. Lower nitrate nitrogen values could be obtained by increasing the volume of the anaerobic tanks up to about 30% of the total volume (instead of 22%) and by increasing the recycling rate. This does not seem a practical proposition because it would necessitate excessive recycling rates and thereby flow through the units, to bring about reduction of a relatively small amount in the nitrate level.

9. France — Olonzac

9.1. This plant treats the distillery wastes associated with the production of 8000 litres of alcohol per day at Olonzac. The waste contains 8 tonnes of suspended solids, 10 tonnes of COD and 4 tonnes of BOD_5 per day.
The waste is passed through a centrifuge to a physical process consisting of neutralisation and flotation. The effluent is then passed through an aeration tank prior to secondary settlement and filtration. Activated sludge from the secondary settlement tank is returned to the aeration tank and the excess sludge to the inlet.

OLONZAC – Distillery Waste Treatment Plant

General View of the Plant.



Control Panel.

10. France — Nice-Ferber

10.1. The site near Nice airport was laid out so that operation of 5 pilot plants could be compared at the same time. A pump with a capacity of 70 m^3/hour was installed to transfer sewage to the site from the pretreatment station at Nice-Ferber. At the site the sewage was degritted, screened and pumped to an elevated feed tank which could feed each pilot plant independently.

10.2. Decanting and flotation apparatus provided by Compagnie Internationale des Eaux, Degrement, ERPAC, Omnium d'Assainissement, Perrier, Saint Gobain Techniques Nouvelles and Pielkenrood Vinitex were installed and tested, using combinations of chemicals, to determine their relative efficiencies in the removal of suspended solids, BOD_5 and COD.

10.3. The characteristics of the resulting sludges were determined and their dewatering properties demonstrated in a Ritterhaus Blecher filter press, a Guinard centrifuge and Westfalia centrifuge.

10.4. The removal of micro-organisms including viruses and salmonellae on the flocs was studied by examining the input and effluent from each pilot plant.

10.5. Tests involving disinfection by means of ozone showed that it was completely effective in the destruction of known amounts of virus and salmonella injected into the PCT treated effluent, given an ozone residual of 0.5 ppm with 15 minutes contact time.

10.6. Tests involving disinfection by passing effluent through an ultra-violet cell at a rate of 2 to 4 m^3/h were not conclusive.

General view of pilot plant at Nice-Ferber.

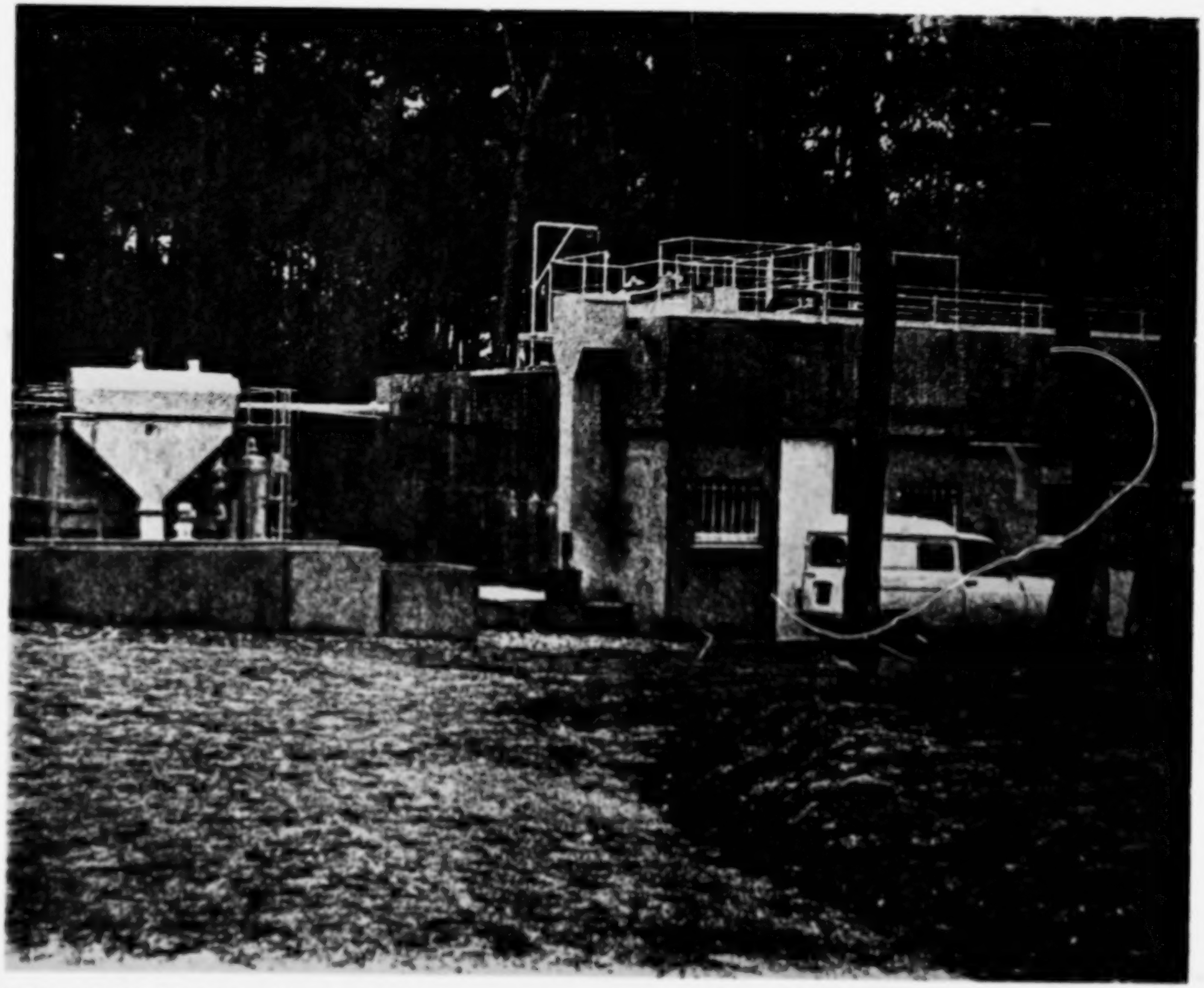
11. France — Talmont Saint-Hilaire

11.1 The area which has a resident population of 400 persons and a summer population of 4000, is served by a separate sewerage system.

11.2. The flow to the works is treated by flocculation using chemical reagents and biological purification. Flotation with minute air bubbles is used to produce a highly concentrated sludge.

11.3. The flocculation-flotation process is used on its own in the peak holiday period but at other times is replaced by a low-load prolonged aeration biological treatment system which makes use of the storage tanks of the summer process to balance flows. The biological tanks are used for aeration and decantation alternatively.

11.4. In winter the effluent complies with a 20 mg/l BOD_5 and 30 mg/l suspended solids standard and in summer with a 70 mg/l BOD_5 and a 30 mg/l suspended solids standard. In summer the flocculation process is assisted by 90 kg/d of alum sulphate and 0.60 kg/d of polyelectrolyte. Sludge is treated with 50 kg/d lime.



TALMONT SAINT HILAIRE – Water Purification Plant.

PLANT DETAILS

APPENDIX B2

APPENDIX No.	TITLE
B2	ITALY
B2/1	Description of Italian Mobile Reverse Osmosis and Ultrafiltration Unit.

1. Italy

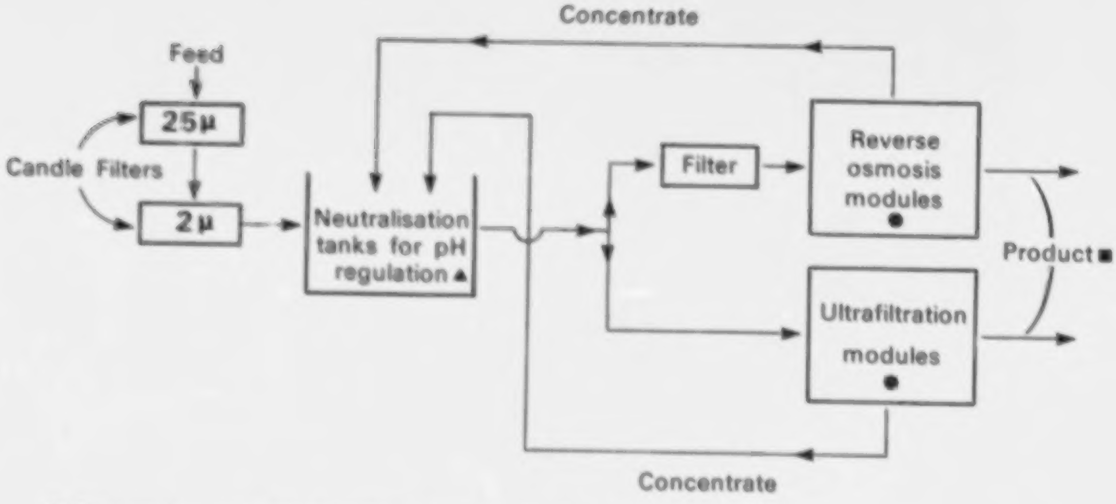
Description of Italian Mobile Reverse Osmosis and Ultrafiltration Unit

1.1. The Italian Institute for Water Research has set up a mobile unit containing three reverse osmosis and three ultrafiltration modules, of the same size as those used in industrial scale plants. The unit contains all the necessary pressurisation and regulation systems. The main characteristics of the modules in use are described in the Table.

1.2. The feed is filtered on (filter) candles and then flows to neutralisation tanks where the pH is regulated by dosing with acid or base. The tanks are sized to provide a residence time of 20 minutes or more. Effluent is then fed to the reverse osmosis and ultrafiltration modules via pressure pumps. A filter before the reverse osmosis modules removes suspended solids with a diameter greater than 3μ. Treated effluent can be partially or completely recycled; the return of the concentrate to the neutralisation tanks allows the concentration of the effluent feed to the plants to be increased continuously.

1.3. The mobile unit includes a laboratory module which enables membranes of different permeabilities to be tested and characterised simultaneously. This module is used to carry out preliminary tests aimed at identifying, the range of rejection values and operating pressures most suitable for the treatment of each effluent.

Diagram of Mobile Reverse Osmosis and Ultrafiltration Unit


Concentrate
Feed
25µ
Candle Filters
2µ
Neutralisation tanks for pH regulation ▲
Filter
Reverse osmosis modules ●
Ultrafiltration modules ●
Product ■
Concentrate

▲ There are two neutralisation tanks, one for ultrafiltration, one for reverse osmosis
● Modules can be operated in series, or in parallel
■ Product water can be re-circulated to either of the neutralisation tanks as necessary

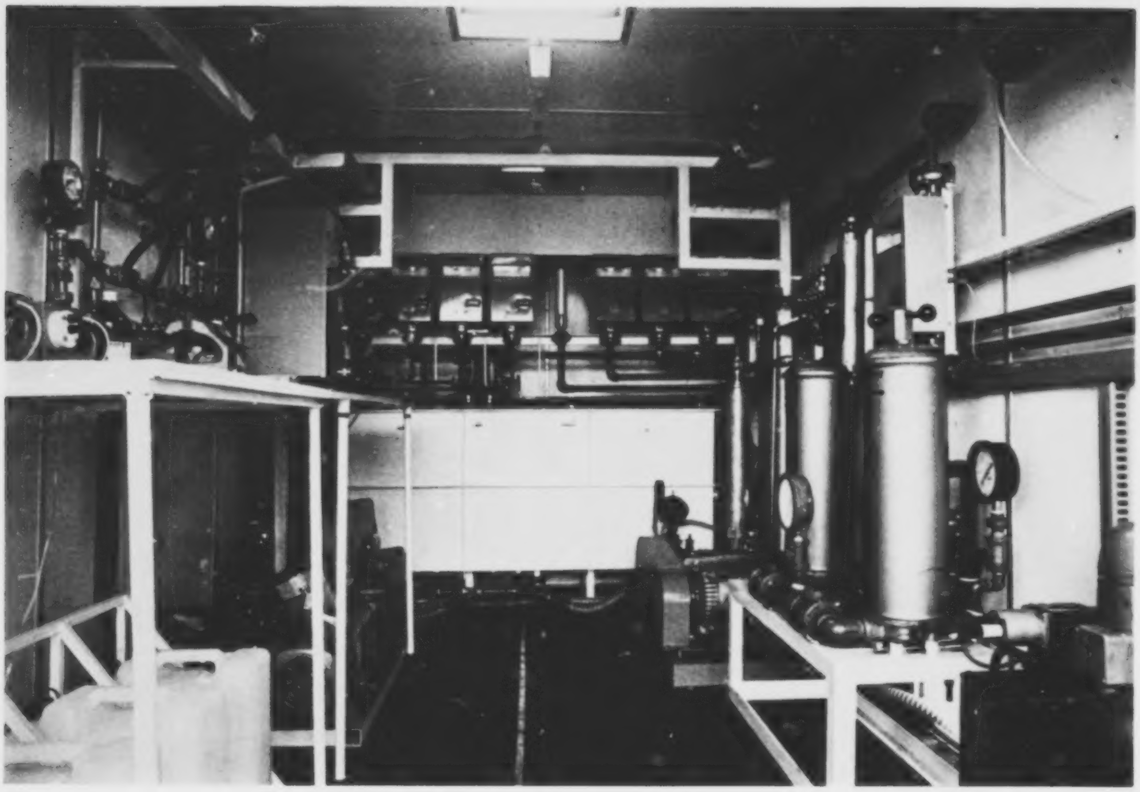
Characteristics of the Reverse Osmosis and Ultrafiltration Modules installed on the Mobile Unit

Module	Type of membranes	Configuration of membranes	Support characteristics	Max. operating pressure 2	Surface area of the membranes (m^2)	Production at max. operating pressure (l/h)	Permeability (l/m^2d atm eff)	Mean Rejection at max. operating pressure (%) ○
U.O.P.	Cellulose acetate type 620	Tubular	Glass fibre	42	1·48	35	12·6	98 △
Gulf General Atomic	Cellulose acetate mod. 4004	Spiral	Porous material	42	2·37	57	14·0	97 △
Du Pont	Polyamidic fibres	Hollow fibre	None	28	164	490	2·4	98 △
Westinghouse Type D150, D180, G150, H180	Cellulose acetate 060, 080 Series	Tubular	Porous sand	7→25	0·86	20→75	28→250	0→90 □

○ Mean rejection = $1 - \frac{2C_p}{Cf+Cc}$ where C_p, C_f, C_c, are the concentrations of the parameters into product, feed and concentrate.

△ Referred to Cl. Feed salinity (as Na Cl): 3000mg/l

□ Referred to saccarose



ISTITUTO DI RICERCA SULLE ACQ
TTAMENTI TERZIARI ACQUE DI SCARI O

ITALY Mobile unit containing reverse osmosis and ultrafiltration modules for the treatment of industrial wastes.

PLANT DETAILS

APPENDIX B3

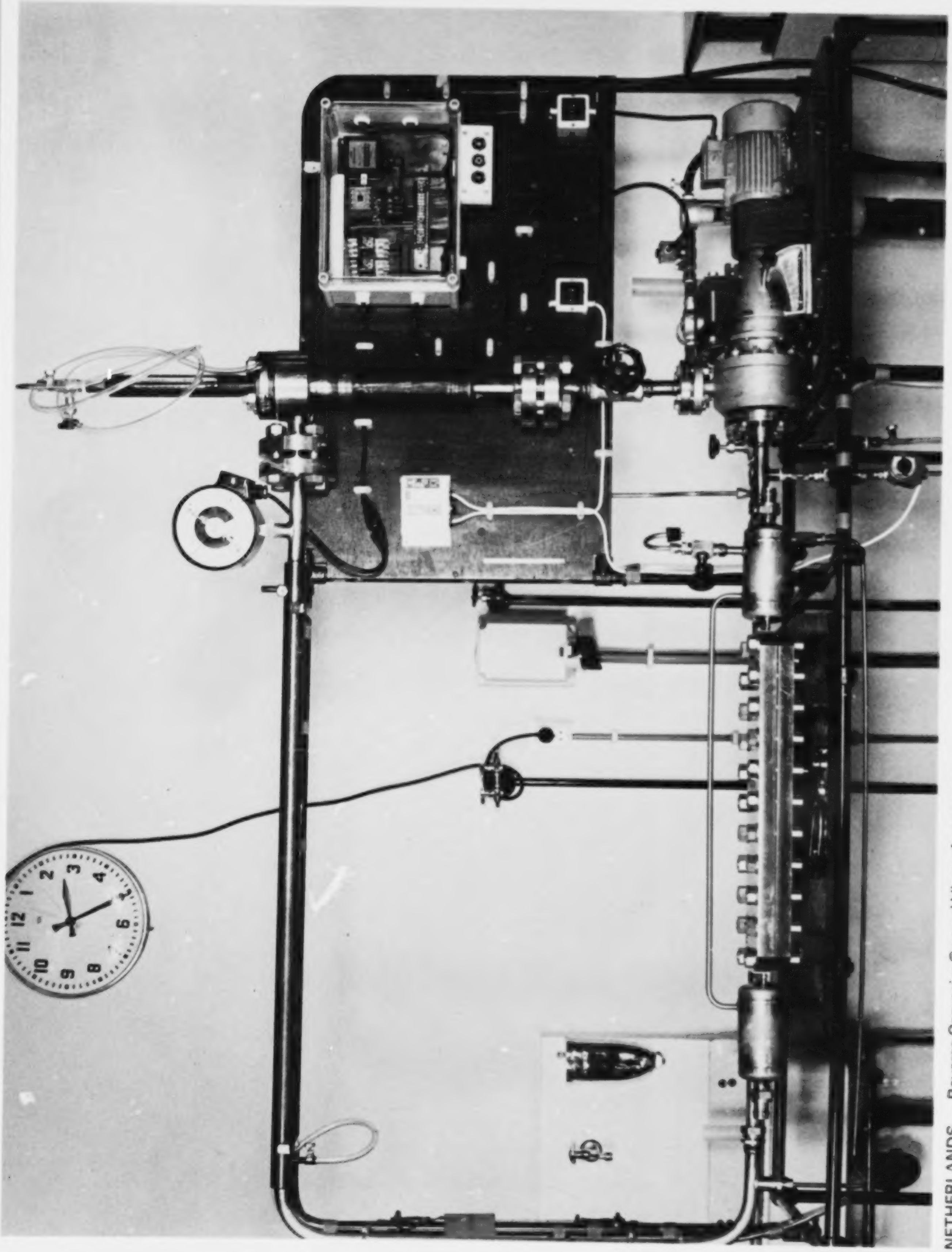
APPENDIX No.	TITLE
B3	THE NETHERLANDS
B3/1	Netherland — TNO 1 Reverse Osmosis — Dynamically formed membranes.
B3/2	Netherland — TNO 2 Combined Nitrogen and Phosphorous in low-loaded activated sludge system operating on oxidation Ditch Principles.

Netherland — TNO 1

Reverse Osmosis — Dynamically Formed Membranes

1.1. Support for the membrane consists of a porous tube. Powdered membrane particles are fed into the effluent in such a way that they are pressed into the pores of the support.

1.2. The membrane, so formed, is capable of treating effluents without pretreatment. Recovery of the membrane is achieved simply by back-washing the fouled membrane out of the pores and then feeding new membrane particles in.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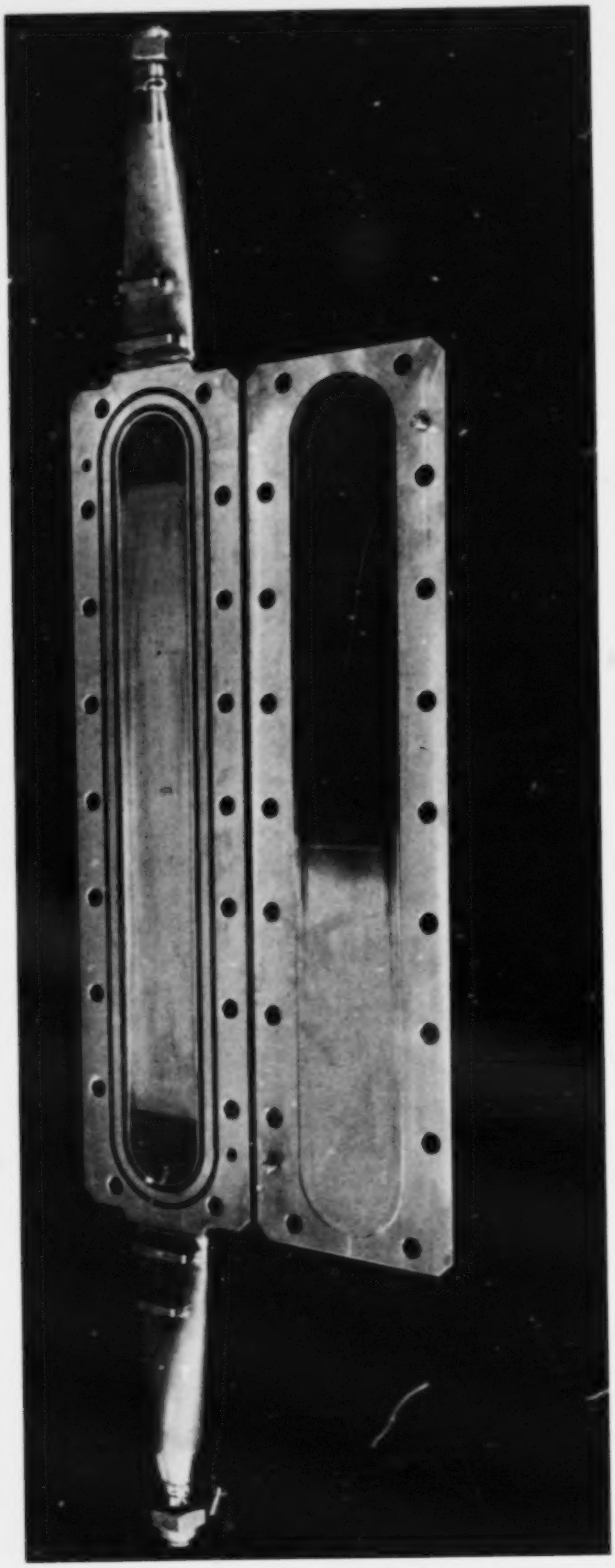
NETHERLANDS – Reverse Osmosis: General View of apparatus



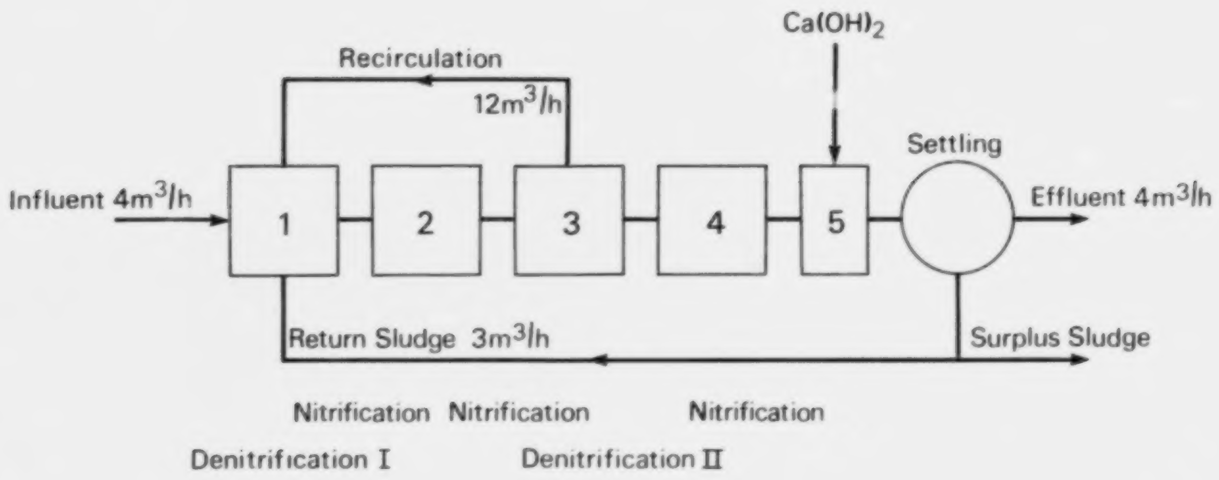
NETHERLANDS – Reverse Osmosis: Close-up of cell.

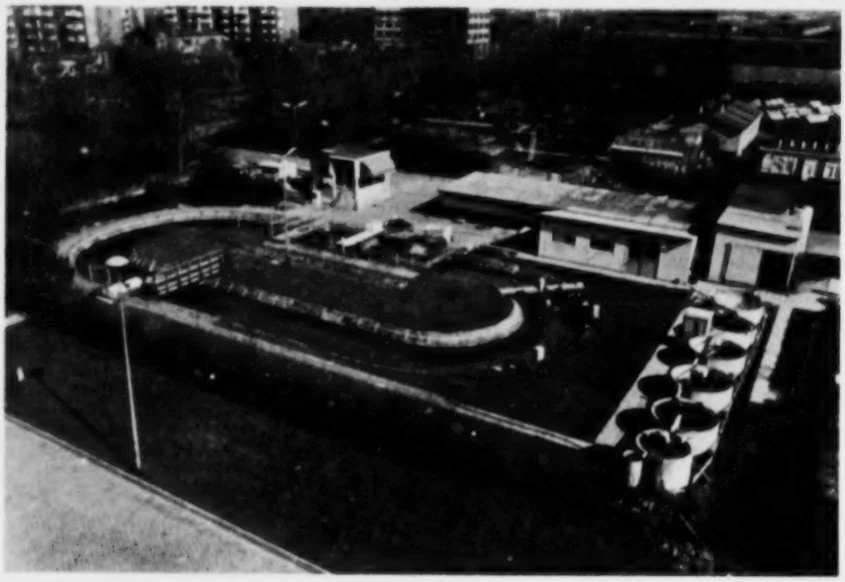
2. Netherland — TNO 2

Combined Nitrogen and Phosphorous in a Low Loaded Activated Sludge System Operating on Oxidation Ditch Principles.

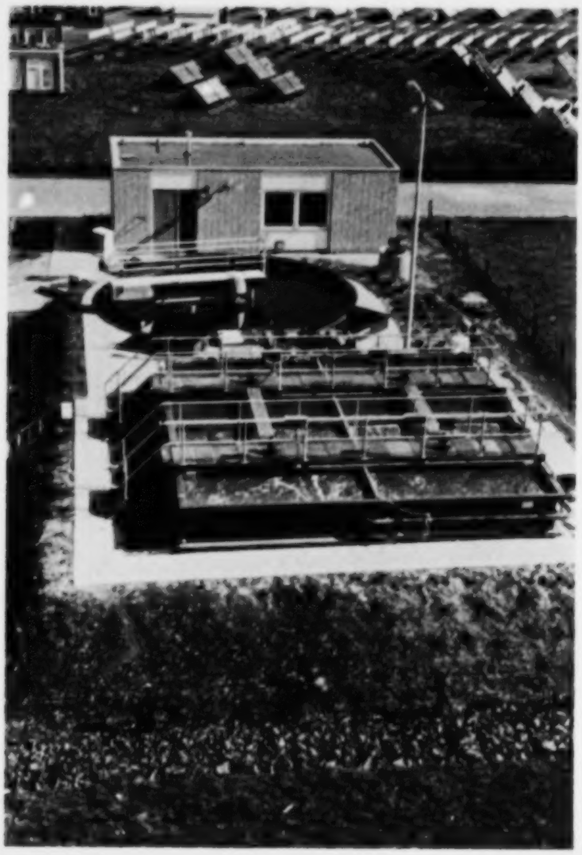
2.1. A schematic layout of the plant is shown in diagrams attached in basin 1, which is stirred mildly without oxygen supply, influent is mixed with nitrified mixed liquor from basin 3 and returned sludge. Nitrification and oxidation of the carbonaceous compounds of the influent takes place in basin 2 and basin 3 at a controlled oxygen concentration of 2 mg/l. In basin 4 denitrification based on endogenous respiration is realised in mild stirring without oxygen supply. Post aeration is carried out in basin 5, in which $Ca(OH)_2$ is also added. The capacity of the plant, not including the settling tank is 158.9 m^3, so that with an influent flow of 4 m^3/h, the detention time is 40 hours.

500 P.E. Plant of TNO Delft

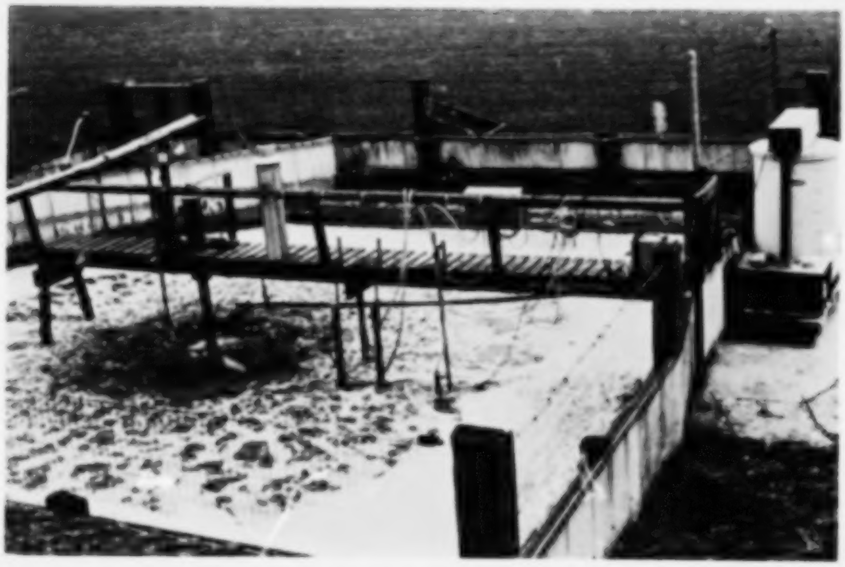

$Ca(OH)_2$
Recirculation
$12m^3/h$
Settling
Influent $4m^3/h$
1
2
3
4
5
Effluent $4m^3/h$
Return Sludge $3m^3/h$
Surplus Sludge
Nitrification
Nitrification
Nitrification
Denitrification I
Denitrification II



NETHERLAND — Oxidation ditch pilot plant at Delft.



NETHERLANDS — Biological purification plant with nitrogen and phosphate removal at Delft.



NETHERLANDS — Phosphorus removal from liquid manure simultaneously with biological COD reduction.

PLANT DETAILS

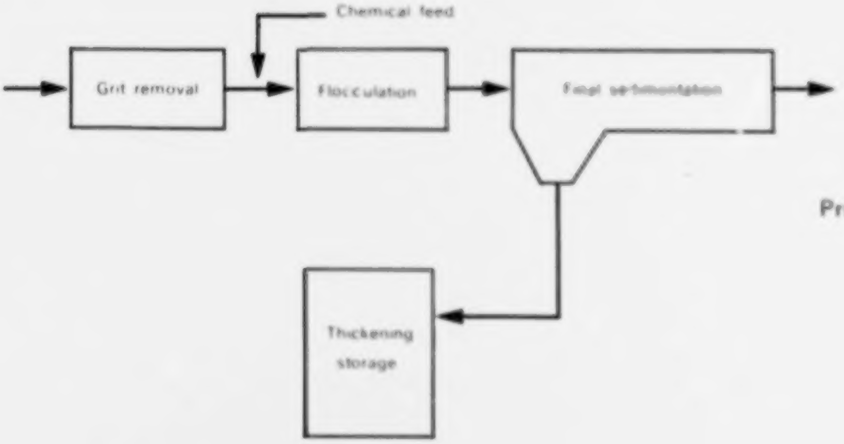
APPENDIX No.		TITLE
B4		NORWAY
	B4/1	Typical description of seventeen different primary and secondary plants.

Norway

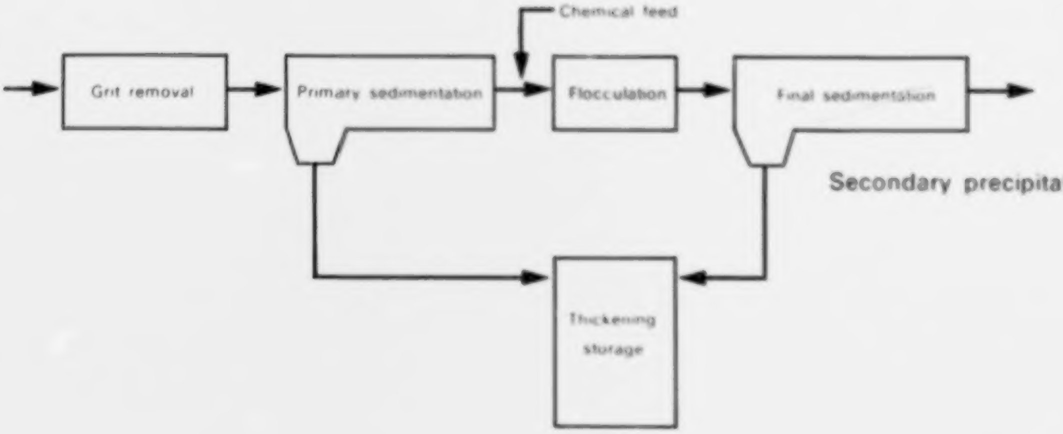
Typical Description of Seventeen Different Primary and Secondary Plants

1.1. The Norwegian Institute for Water Research (NIVA) has made a survey of 17 different primary and secondary plants for construction costs. All these plants are located in the south-eastern part of Norway. The treatment plants cater for populations from 1750 to 60,000. Flow diagrams are given for both primary and secondary precipitation plants. The photographs show typical details of Norwegian plants.

Flow Diagram Primary and Secondary Precipitation Plants


Chemical feed
Grit removal
Flocculation
Final sedimentation
Thickening storage

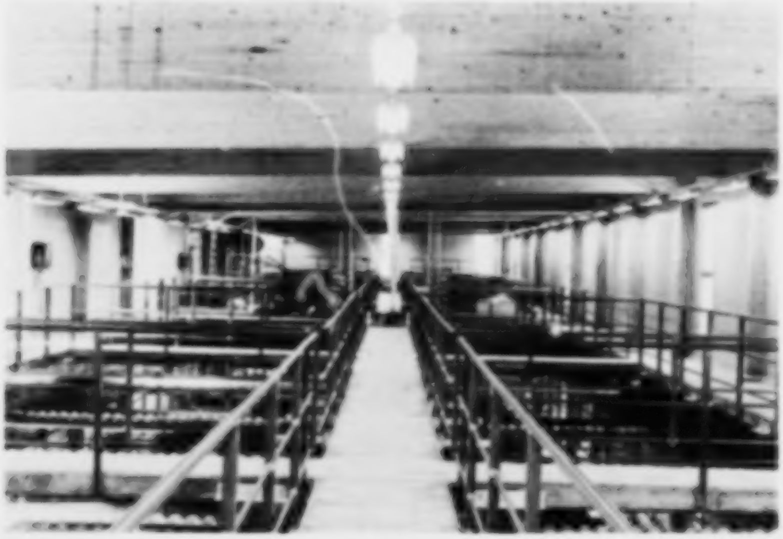
Primary precipitation


Chemical feed
Grit removal
Primary sedimentation
Flocculation
Final sedimentation
Thickening storage

Secondary precipitation

NORWAY – Moelv sewage treatment plant.

NORWAY – Hopper for flocculants. Kløfta sewage treatment plant.



NORWAY – Primary sedimentation, flocculation and final sedimentation. Eidsvoll sewage treatment plant.

NORWAY — Flocculation basins with vertical mounted stirrers. Breiskallen sewage treatment plant.

NORWAY — Typical chemical feed equipment for Aluminiumsulphate precipitation. Fjellfoten sewage treatment plant.

PLANT DETAILS

APPENDIX No.		TITLE
B5	B5/1	UNITED KINGDOM
	B5/1	United Kingdom 1 — City of Bath — Oxygen to treat wastewater in pumping main.
	B5/2	United Kingdom 2 — Coleshill Pilot AWT Plant.
	B5/3	United Kingdom 3 — Davyhulme Pilot AWT Plant.
	B5/4	United Kingdom 4 — Ipswich — Physical-chemical treatment work at Cliff Quay.
	B5/5	United Kingdom 5 — Stevenage Pilot AWT Plant.
	B5/6	United Kingdom 6 — Palmersford Wastewater Treatment Works.

United Kingdom 1

City of Bath — Oxygen to Treat Wastewater in Pumping Main

1.1. Bath is served by a largely combined sewerage system discharging under gravity to a main pumping station at Twerton. Flows up to 48 x 10^3 m^3/d (2DWF) are pumped through a long main to the treatment works at Saltford; excess flows are given storm settlement at Twerton. The general arrangement of the pumping station and storm holding tanks is shown in Fig. 1. This works is under the Control of the Wessex Water Authority.

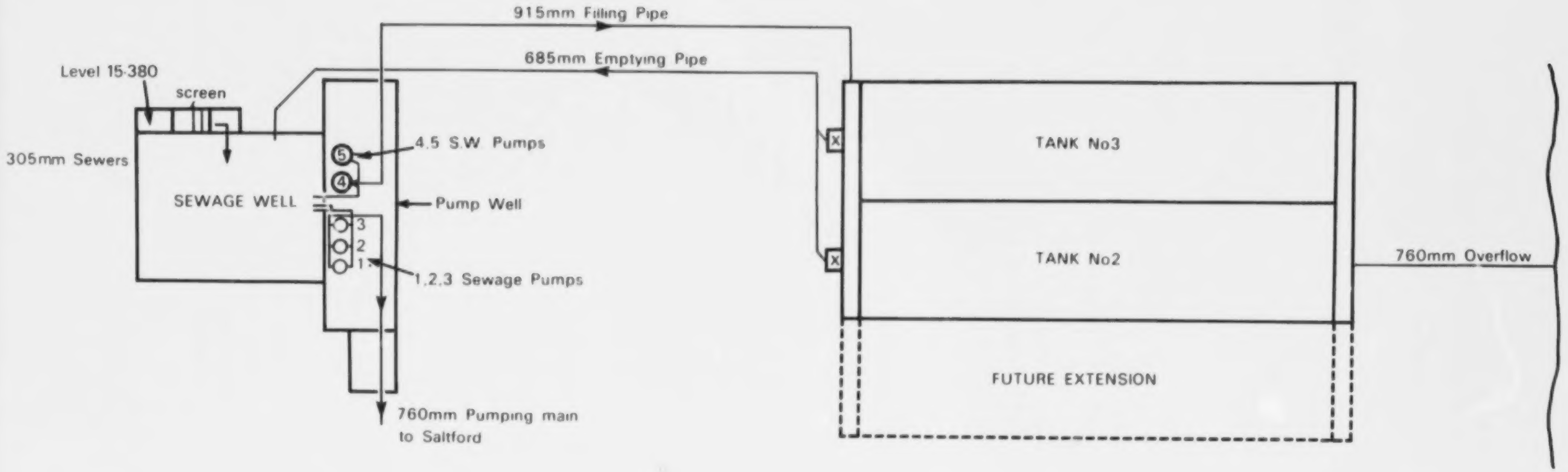
1.2. The pumping station has three multi-speed sewage pumps of which the two duty pumps operate in four combinations, the average maximum working head being 26m. As the sewage level rises in the wet well with increasing incoming flow, pumping rates increase and conversely, as the level falls, pumping rates diminish. The cut-in levels are determined by the need to have a positive prime on the pumps during start-up. Cut-out levels ensure that the outfall sewer is flushed daily during dry weather. Storage in the wet well between cut-in and cut-out levels partially balances diurnal flow variations and prevents too frequent actuation of switchgear. Sewage is pumped to an elevation of about 18.60m and the static lift can vary from under 4.69m to 8.86m. Control of pumping is automatic, no-flote electrodes actuating the pumps in sequence at predetermined levels and speeds.

1.3. The rising main, laid in 1914, consists of 12 foot lengths of Class B cast-iron pipe with run-lead joints. It is 8.16 km long, has a diameter of 760 mm, a volume of 3600 m^3 and an internal surface area of 20,000 m^2. Its profile is shown in Fig 2 which also indicates the position of air valves and vent columns.

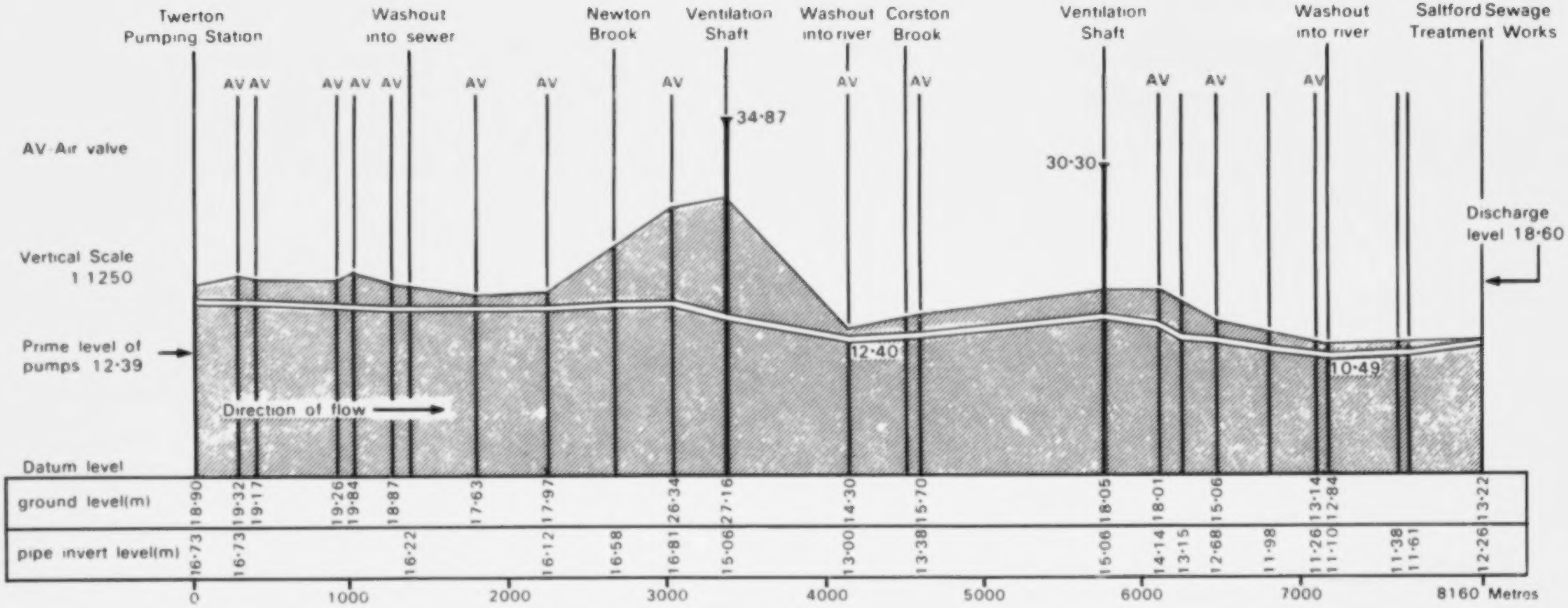
1.4. The sewage treatment works at Saltford is a conventional biological filtration plant which was first constructed in 1914, extended in 1967 and is now about 40% overloaded both hydraulically and biologically.

1.5. A schematic representation of the oxygen injection system is attached. Liquid oxygen supplied by tanker is stored in a 10 tonnes capacity, insulated vessel (A) from which it is vaporised (B) and piped to a small control box (C) in the pumping station, containing a gas flow meter and a pressure switch providing automatic shut-down of oxygen supply when pumping stops. Oxygen is fed from the control box via a fine nozzle injector into the outlet pipes (D) from each of the sewage pumps; these injection points were chosen to provide maximum pressure and good mixing. A relay from each pump switches off oxygen to the pump when it is not operating. Pumping is controlled automatically and the only attention required by the oxygen equipment is a daily check of injection rate and tank pressure. Oxygen requirements vary with sewage strength and flow; injection rate is usually maintained at a level allowing dissolved oxygen to be detected at all times in settled sewage at the works. In summer the optimum injection rate was found to be about 54 kg/h (1.3 tonnes/day).

Appendix B5/1
Fig. 1

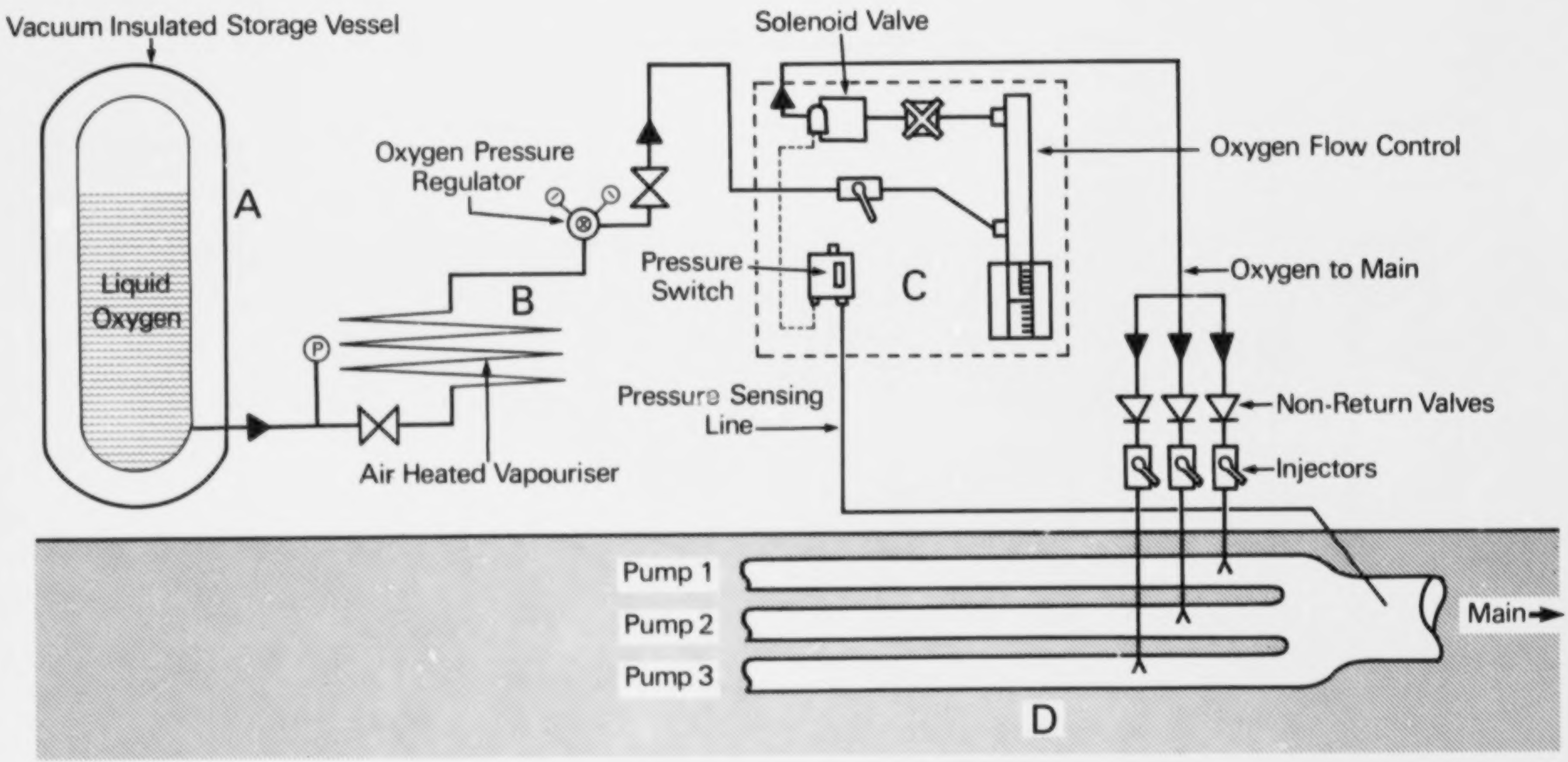

915mm Filling Pipe
685mm Emptying Pipe
Level 15·380
screen
305mm Sewers
SEWAGE WELL
4.5 S.W. Pumps
5
4
Pump Well
3
2
1
1,2,3 Sewage Pumps
760mm Pumping main to Saltford
TANK No3
TANK No2
FUTURE EXTENSION
760mm Overflow

Layout Plan of Bath Pumping Station and Storm- water Tanks


Twerton Pumping Station
Washout into sewer
Newton Brook
Ventilation Shaft
Washout into river
Corston Brook
Ventilation Shaft
Washout into river
Saltford Sewage Treatment Works
AV AV
AV AV AV
AV
AV
AV
AV
AV
AV AV
AV
34·87
30·30
AV·Air valve
Vertical Scale 1 1250
Prime level of pumps 12·39
Discharge level 18·60
Direction of flow
12·40
10·49
Datum level
ground level(m)
18·90 19·32 19·17 19·26 19·84 18·87 17·63 17·97 26·34 27·16 14·30 15·70 18·05 18·01 15·06 13·14 12·84 13·22
pipe invert level(m)
16·73 16·73 16·22 16·12 16·58 16·81 15·06 13·00 13·38 15·06 14·14 13·15 12·68 11·98 11·26 11·10 11·38 11·61 12·26
0
1000
2000
3000
4000
5000
6000
7000
8160 Metres

Section of 760mm diameter pumping main from Bath Pumping Station to Saltford Sewage Treatment Works

Appendix B5/1
Fig.3


Vacuum Insulated Storage Vessel
Liquid Oxygen
A
P
Air Heated Vapouriser
B
Oxygen Pressure Regulator
Solenoid Valve
Oxygen Flow Control
Pressure Switch
C
Pressure Sensing Line
Oxygen to Main
Non-Return Valves
Injectors
Pump 1
Pump 2
Pump 3
Main
D

Twerton, Bath Pumping Station – Schematic arrangement of oxygen injection equipment.

United Kingdom 2

Coleshill Advanced Wastewater Treatment Pilot Plant

General

2.1. The pilot plant occupies 1.5 hectares on the Coleshill sewage works of Tame Division Severn-Trent Water Authority, serving part of eastern Birmingham.

2.2. From twelve outline designs submitted, the Department chose one involving the novel concept of bringing treatment units to the feed sewage, instead of vice-versa providing almost unlimited flexibility. There are two principal treatment streams, each with dwf 450m^3/d.

Inlet Works and Balancing

2.3. Sewage is pumped from one or both of the sewers feeding the Coleshill sewage works — that from the Chelmsley Wood sewer being wholly domestic, and that from the Meriden sewer containing some industrial waste. The two pumping stations each contain duplicate mobile self-priming centrifugal pumps with individual capacity up to 1500m^3/d. Sewage is delivered through 150mm diameter mains to a splitter/mixer tank at the head of the inlet works. Thereafter it flows in two entirely independent streams through the inlet works and the main experimental area of the plant.

2.4. The flow in each stream is screened by 20mm-clearance mechanically-raked curved-bar screens, with provision for removing screenings or macerating them and returning them to flow. In addition a wedge-wire screen with apertures down to 0.75mm is provided for one stream, and a perforated-plate screen with 3mm diameter holes for the other; either or both may be by-passed. Each stream passes through an air-evacuated grit tank and a 100mm-throat flume, and is regulated by a cut-water gate responding to flow-meter signal. Within the limits 0.5 — 3.0 dwf flow in each stream may be

a. steady

b. varied diurnally according to any required pattern

c. matched to that in the main Coleshill sewage works.

Surplus flows are returned to the main Coleshill sewage works. Future storage tanks will enable a range of industrial effluents to be added at controlled rates.

2.5. Each stream has provision for flow-balancing. The 5m diameter and 60m^3 balancing tanks are equipped with mechanical stirrers and scrapers (one is experimentally fitted with an automatically-controlled variable-level outlet weir) and variable-speed pumps. They may be operated in:

a. 'feed-off' — flow exceeding a preset rate is diverted to the tank, to be pumped back as and when flow diminishes

b. 'through flow' — the whole flow passes through the tank, but is pumped out at a preset rate (the contents of the tank being mixed)

c. 'through flow with settlement' — the tank acts in a primary sedimentation role.

d. 'constant load' — the flow passed forward may be adjusted automatically to take into account variations in a selected parameter.

2.6. Process liquors (including sludge filtrates) from each stream are separately returned to flow either direct, through the appropriate balancing tanks, or through process liquor holding tanks (of which there is one per stream, similar in size to a balancing tank, and similarly equipped).

2.7. Two pairs of hopper bottomed sludge consolidation tanks, each 4m diameter and 25m^3 capacity, are equipped with search-arms for decanting supernatant liquor. (One 2m diameter sedimentation tank has been experimentally fitted with a picket-fence thickener).

2.8. The single or two-stage recarbonation units employ carbon dioxide for pH reduction and have a sedimentation tank between stages.

2.9. Three 1.25m diameter by 3.5m high multi-media filters containing anthracite and sand, with gravel base, can each accept 1.5dwf. They may be used in any combination, in pressure downflow or (at half-rate) in open-top gravity modes. Air-scour and backwash are actuated by timer or resistance-to-flow transducer.

2.10. Three sets each of two 1.5m diameter by 5m high activated carbon columns (each set containing 2650 kg of granular carbon) may be used in upflow (series) and downflow (parallel) modes. Contact time is 20 minutes at 3 dwf (two sets assumed in operation). Carbon size is initially 12.22 BS sieve. Mobile ancillary units comprise:

a. influent pump well, pumps and auto-control equipment

b. treated effluent backwash storage; backwash pumps are automatically controlled and linked with air scour

c. fresh and spent carbon handling and storage units for column replenishment.

2.11. A fixed unit of two 0.225m diameter by 3m high multi-media filters with sand and anthracite media and nine 0.15m by 4m high granular activated carbon columns, overall throughput 12m^3/d, is also provided.

2.12. Four activated sludge surface aeration tanks each 4m square by 2m deep are fitted with adjustable-level variable-speed aerators (oxygen transfer rate 30-200mg/1); net total retention is 4h at dwf. The tanks may be arranged in series or parallel. Sludge return is by gravity from an adjacent mobile sedimentation tank.

2.13. An ordered plastics-media biological filter, 6.6m x 2.4m x 3.6m deep (57m^3 effective volume) with alternative reciprocating and fixed-spray distributors may be used as a single-stage or variable volume two-stage unit. A random plastics media filter 5.25m diameter by 4.5m deep (64m^3 effective volume) has a rotating variable-speed distributor capable of operation with varying depths of media.

2.14. Four 3.5m effective-lift screw-pumping units are provided to transfer flow between treatment units when gravitational feed is not possible — eg to pump mixed liquor from activated sludge units to adjacent sedimentation tank (return sludge flows by gravity).

2.15. Other mobile pumping and pump-well assembles are provided (eg for feed and recirculation to biological filters).

Chemical Preparation and Dosing

2.16. Lime is likely to be the principal chemical dosed. A standard 25t silo to take powdered hydrated lime from tankers is mounted on a load-cell weighing system. Lime is slurried by automatic weighbatch to preset water volume. The mixture is stirred and aged for 8h, and transferred to 26h capacity stock tanks for conveyance by ring main. Dosing is controlled by pH of sewage after liming, or by sewage flow (dose measured by magnetic flowmeter). Iron or aluminium salts are stored in an 11m^3 GRP 20d capacity tank; after dilution they are transferred to 24h capacity stock tanks before dosing to flash-mixer, or in-line. Sulphuric or hydrochloric acid (alternatives to carbon dioxide for pH correction) are stored in a 20m^3 GRP — propylene tank and dosed under automatic control.

Activated Carbon Regeneration

2.17. A seven-hearth 1.5m diameter furnace, with five burners each capable of 200,000 BThU/h, is provided for regenerating spent granular activated carbon. Later it will be used for lime-sludge calcining, sludge incineration, and for developing methods of making carbon (eg from sludge). Ancillary carbon screening and handling facilities allow carbon losses to be measured. This unit has been provided by Environment Canada, who are very kindly loaning it to the Department.

Main Control Gallery and Mobile Treatment Units

2.18. Each feed stream is separately piped to the 66m long two-storey fixed gantry on the main experimental section of the plant; one stream along each face.

2.19. All wastewater treatment units are mobile and can be offered-up to any of ten points on each gantry face. They are towed by the site Land Rover on the main working area — 10500m^2 of concrete pavement laid in 5m x 5m bays, able to accept tare weights up to 20 t.

2.20. The control gallery of the gantry and the operating platforms of the mobile units are both 2.4m above pavement level. Each face of the gallery consists of sliding wall-sections which may be moved aside to allow access to the operating platforms, and to admit unit control panels which fit flush with the gallery wall-sections and are sealed-in with plastic hoods. Thus main controls may be operated and instruments read under cover. Piped services under the control gallery floor (one set for each stream) convey feed wastewater, filtrates, backwashings, sludges, treated effluent (to Coleshill sewage works inlet), lime slurry, liquid flocculant chemicals, acid, and washdown water (final effluent from Coleshill sewage works).

2.21. All mobile treatment units have subframes with three standard sockets: one for the spigot of a towing-wheel assembly, two for the spigots of trailing-wheel assemblies. Each assembly has a jack (operated by hand, or by a power-driven pump carried on a trolley). When a unit is to be moved it is:

a. emptied of liquid

b. fitted with the three wheel assemblies

c. jacked up

d. towed and positioned by the site Land Rover, which has remote-controlled creeper-transmission.

2.22. Units are generally symmetrical and may be offered to either face. When correctly positioned, a unit is jacked down on to hardwood blocks to a level giving the hydraulic gradient required. Flow-connections are then made with purpose-cut standard uPVC pipes and fittings.

2.23. The two 1.8m x 1.2m deep flash-mixer-flocculator units each give 17 minutes retention at 3dwf. Flocculator paddles are variable-speed. Lime and other flocculants are added at the flash-mixer stage, or direct to flow line. Flow and pH controls are provided.

2.24. A range of circular sedimentation tanks (see table below) enables the effects of different upflow rates and retentions to be studied without flow-rates being altered. Each is 3m effective depth, has a 7½° sloping floor, mechanical floor wall and scum scrapers, air-actuated desludging and sludge recirculation and transfer. The positive-displacement sludge pumps are controlled by level probes and have hand-set variable-speed drives from which a 4-20mA signal may be taken to indicate quantities discharged.

Tank		at dwf		at 3 dwf	
Diameter (m)	Area (m^2	Upward flowrate (m/h)	Retention (h)	Upward flowrate (m/h)	Retention (h)
* 2.00	3.1	6.00	0.5		
* 2.45	4.7	4.00	0.75		
* 3.01	7.1	2.71	1.11		
* 3.67	10.6	1.89	1.50	5.35	0.56
* 4.50	15.8	1.19	2.52	3.58	0.84
5.52	23.9	0.79	3.80	2.37	1.27
6.76	36.0	0.53	5.70	1.58	1.90
8.28	54.0			1.05	2.86
10.15	80.2			0.70	4.29

Two of each of the tanks asterisked (*) are currently available.

Sludge Treatment

2.25. Two 4.5m diameter flat-bottomed stirred and scraped tanks, 3.25m deep, are provided for storing sludges derived from chemically-aided settlement; two similar tanks 3.5m diameter are provided for biological-treatment sludges. Flotation thickening, chemical conditioning and a 1.75m^2 variable-pressure filter plate press (total volume 2.75m^3 in 60 chambers) are housed in a sludge treatment building, which also contains facilities for feeding and monitoring manufacturers' sludge-treatment pilot plants. Filtrates may be returned direct to the relevant stream of feed wastewater, either below the inlet works, or to holding or balancing tanks.

Sidestream Facilities

2.26. Several small streams of screened and degritted wastewater (from feed surplus to the requirements of the two principal streams) are available adjacent to the inlet works at a height of 4m above concrete pavement level. These streams will be used for evaluations of manufacturers' pilot plants, processes, equipment, etc.

Instrumentation, Data Logging, Laboratory Facilities and Power

2.27. Overall plant performance is monitored by sensors measuring the turbidity, total organic carbon (by ultra-violet absorption), pH, dissolved oxygen, ammonia and temperature of effluents (and, where relevant, of wastewater). The 4-20mA output signal is connected to one of ten 3-channel chart recorders which may also be used to monitor the performance of a number of mobile treatment unit control systems. The recorders operate at a common chart speed of 1cm/h and have charts scaled 0-100, with 50 grid divisions and left-hand zero. A Highway system of data transmission, developed by WRC for water and sewage applications, is being prepared for the plant. The 4-20mA signals will be coded and transmitted through a single co-axial cable common to all transmitters, to a central receiving and data-logging installation, which will ultimately provide a basis for automatic control and unattended operation.

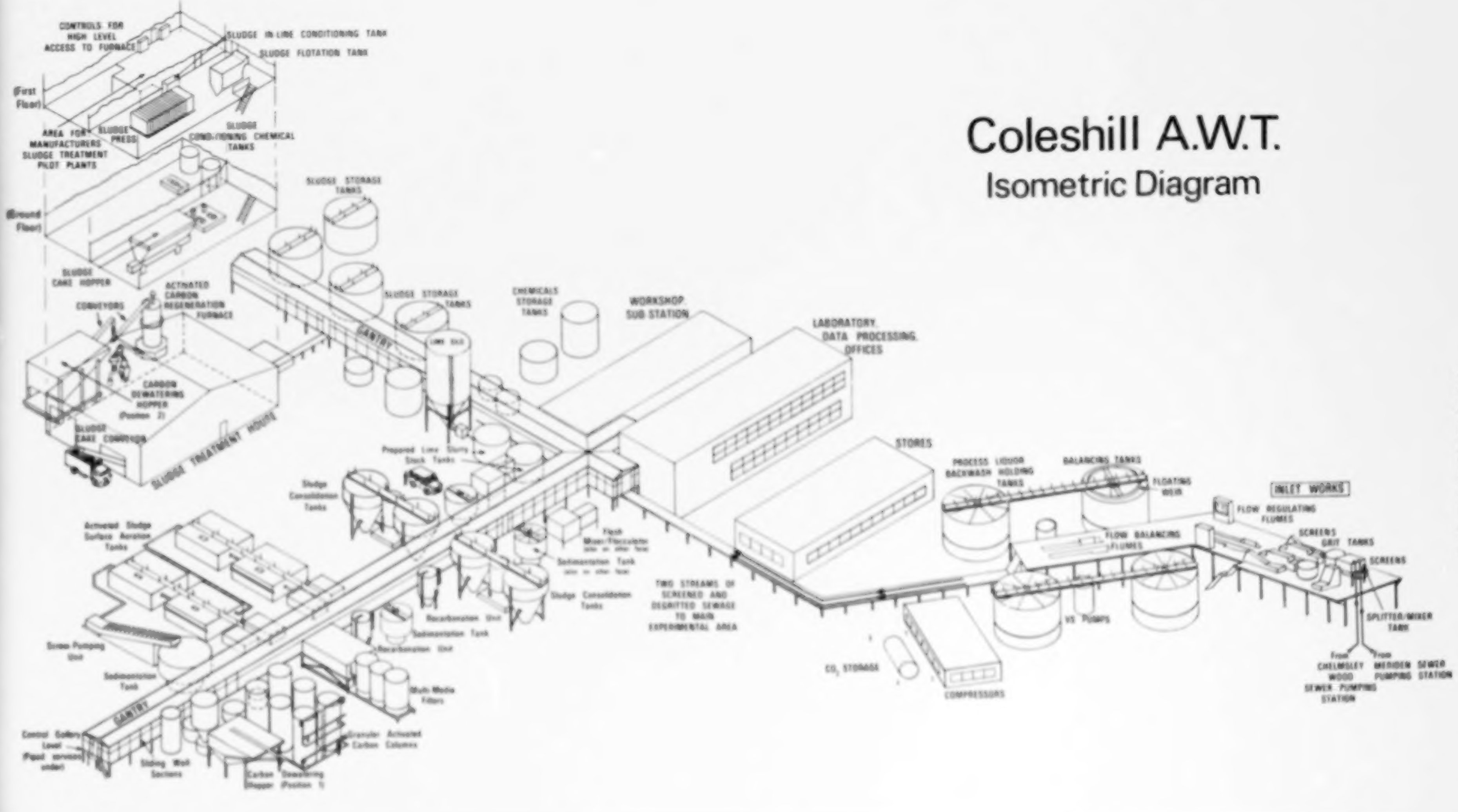
2.28. Standard automatic sampling equipment is programmed to collect up to 24 samples at equal time intervals, or a bulked sample from samples taken at equal time intervals or proportional to flow.

2.29. The plant laboratory has a specialised role covering the monitoring of chemical feeds, of certain effluent parameters at each treatment stage, and of sludge dewatering properties; general laboratory services for plant operations are also performed. Many routine analyses (eg BOD, COD) are carried out at laboratories belonging to Tame Division, Severn-Trent Water Authority, equipped to deal quickly with large numbers of samples. Some determinations are made at WRC Stevenage, eg metals in sludge and bacteriological work.

2.30. Power provided from the main Coleshill sewage works 11kV ring main is fed to standard cubicles at 440 V three-phase 50 Hz, and then to 60 amp 5-pin sockets on the gantry, each with kWh meter. Single-phase 230 V and 110 V supplies are available for portable tools and instruments. Control and monitoring circuits are connected through 20-pin sockets to 5 x 37 multicore cables running to a central terminal cubicle, signals reaching which may be connected to recording instruments and ultimately to the data-logger.

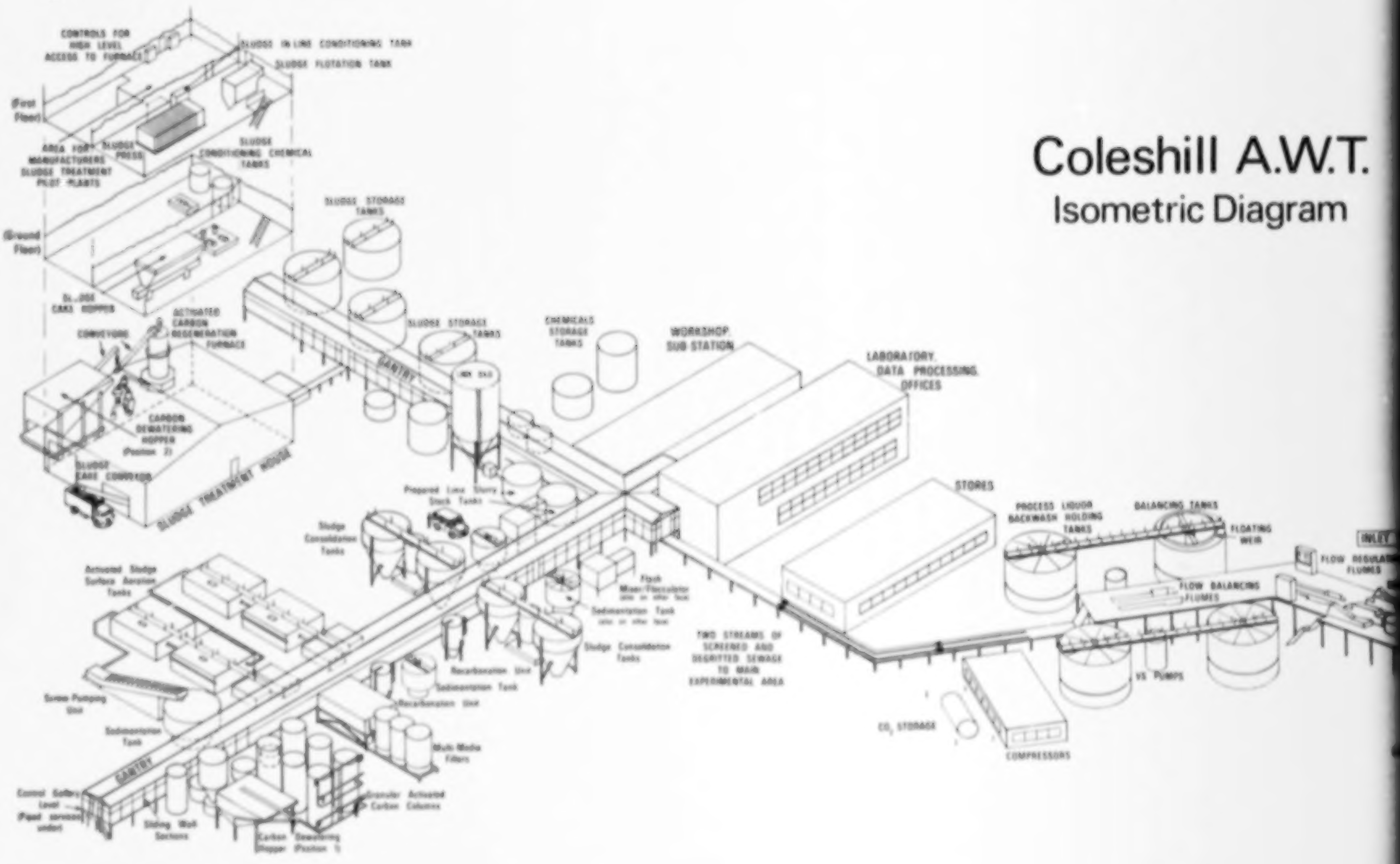
Coleshill A.W.T.

Isometric Diagram

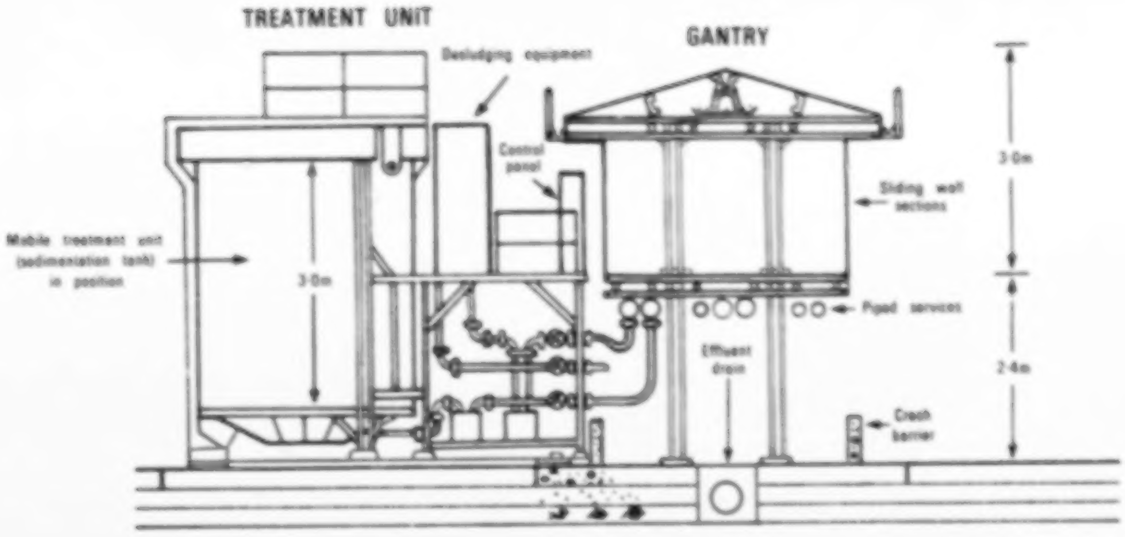

CONTROLS FOR HIGH LEVEL ACCESS TO FURNACE
SLUDGE IN-LINE CONDITIONING TANK
SLUDGE FLOTATION TANK
(First Floor)
AREA FOR MANUFACTURERS SLUDGE TREATMENT PILOT PLANTS
SLUDGE PRESS
SLUDGE CONDITIONING CHEMICAL TANKS
(Ground Floor)
SLUDGE STORAGE TANKS
SLUDGE CAKE HOPPER
ACTIVATED CARBON REGENERATION FURNACE
CONVEYORS
SLUDGE STORAGE TANKS
GANTRY
LIME SILO
CARBON DEWATERING HOPPER (Position 2)
SLUDGE CAKE CONTAINER
SLUDGE TREATMENT HOUSE
CHEMICALS STORAGE TANKS
WORKSHOP SUB STATION
LABORATORY, DATA PROCESSING, OFFICES
Prepared Lime Slurry Stock Tanks
Sludge Consolidation Tanks
Activated Sludge Surface Aeration Tanks
Flash Mixer/Flocculator
Sedimentation Tank
Sludge Consolidation Tanks
Recarbonation Unit
Sedimentation Tank
Recarbonation Unit
Screw Pumping Unit
Sedimentation Tank
Multi Media Filters
GANTRY
Control Gallery Level (Pipes services under)
Sliding Wall Sections
Carbon Dewatering Hopper (Position 1)
Granular Activated Carbon Columns
TWO STREAMS OF SCREENED AND DEGRITTED SEWAGE TO MAIN EXPERIMENTAL AREA
STORES
CO₂ STORAGE
COMPRESSORS
PROCESS LIQUOR BACKWASH HOLDING TANKS
BALANCING TANKS
FLOATING WEIR
FLOW BALANCING FLUMES
VS PUMPS
INLET WORKS
FLOW REGULATING FLUMES
SCREENS
GRIT TANKS
SCREENS
SPLITTER/MIXER TANK
From CHELMSLEY WOOD SEWER PUMPING STATION
From MERIDEN SEWER PUMPING STATION

Coleshill A.W.T.

Isometric Diagram

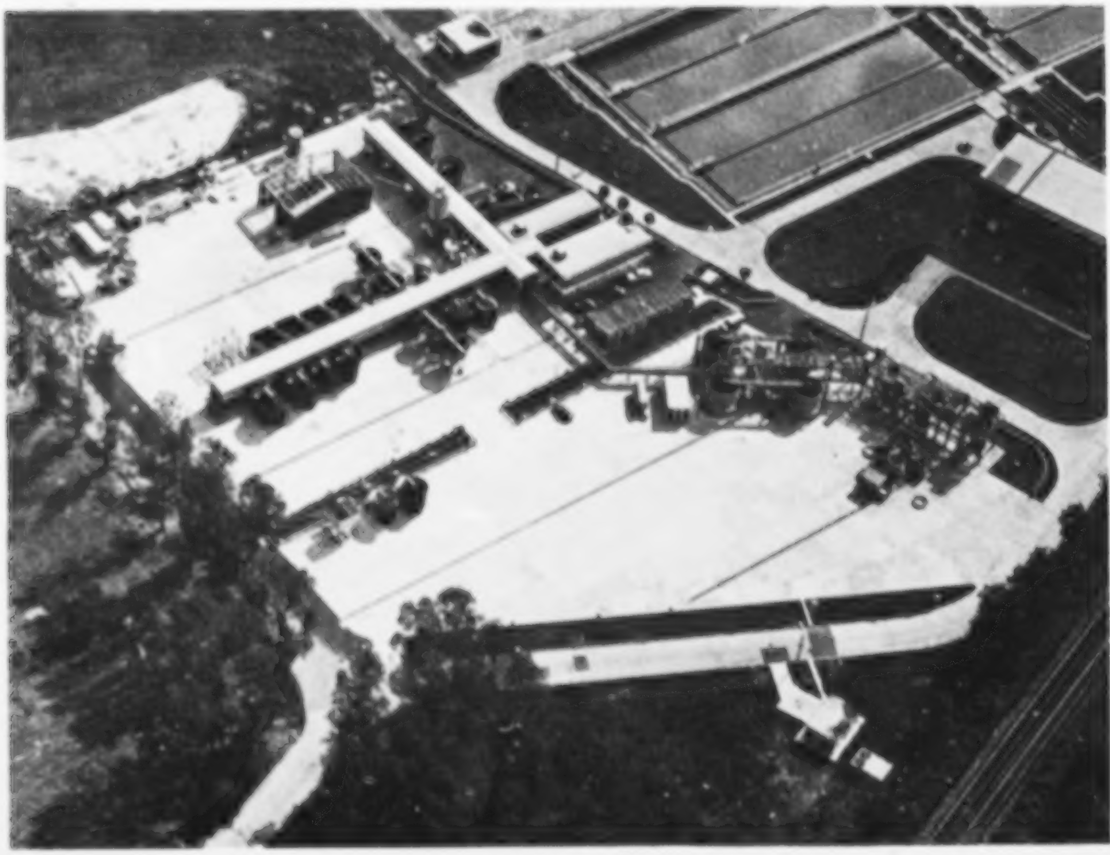

CONTROLS FOR HIGH LEVEL ACCESS TO FURNACE
SLUDGE IN LINE CONDITIONING TANK
SLUDGE FLOTATION TANK
(First Floor)
AREA FOR MANUFACTURERS SLUDGE TREATMENT PILOT PLANTS
SLUDGE PRESS
SLUDGE CONDITIONING CHEMICAL TANKS
(Ground Floor)
SLUDGE CAKE HOPPER
ACTIVATED CARBON REGENERATION FURNACE
CONVEYORS
CARBON DEWATERING HOPPER (Position 2)
SLUDGE CAKE CONVEYOR
SLUDGE TREATMENT HOUSE
SLUDGE STORAGE TANKS
SLUDGE STORAGE TANKS
GANTRY
CHEMICALS STORAGE TANKS
WORKSHOP. SUB STATION
LABORATORY. DATA PROCESSING. OFFICES
STORES
Prepared Lime Slurry Stock Tanks
Sludge Consolidation Tanks
Activated Sludge Surface Aeration Tanks
Flash Mixer/Flocculator (also on other face)
Sedimentation Tank (also on other face)
Sludge Consolidation Tanks
Recarbonation Unit
Sedimentation Tank
Recarbonation Unit
Screw Pumping Unit
Sedimentation Tank
Multi Media Filters
GANTRY
Control Gallery Level (Pipe services under)
Sliding Wall Sections
Granular Activated Carbon Columns
Carbon Dewatering Hopper (Position 1)
TWO STREAMS OF SCREENED AND DEGRITTED SEWAGE TO MAIN EXPERIMENTAL AREA
PROCESS LIQUOR BACKWASH HOLDING TANKS
BALANCING TANKS
FLOATING WEIR
INLET
FLOW REGULA
FLUMES
FLOW BALANCING FLUMES
VS PUMPS
CO_2 STORAGE
COMPRESSORS

Coleshill A.W.T.

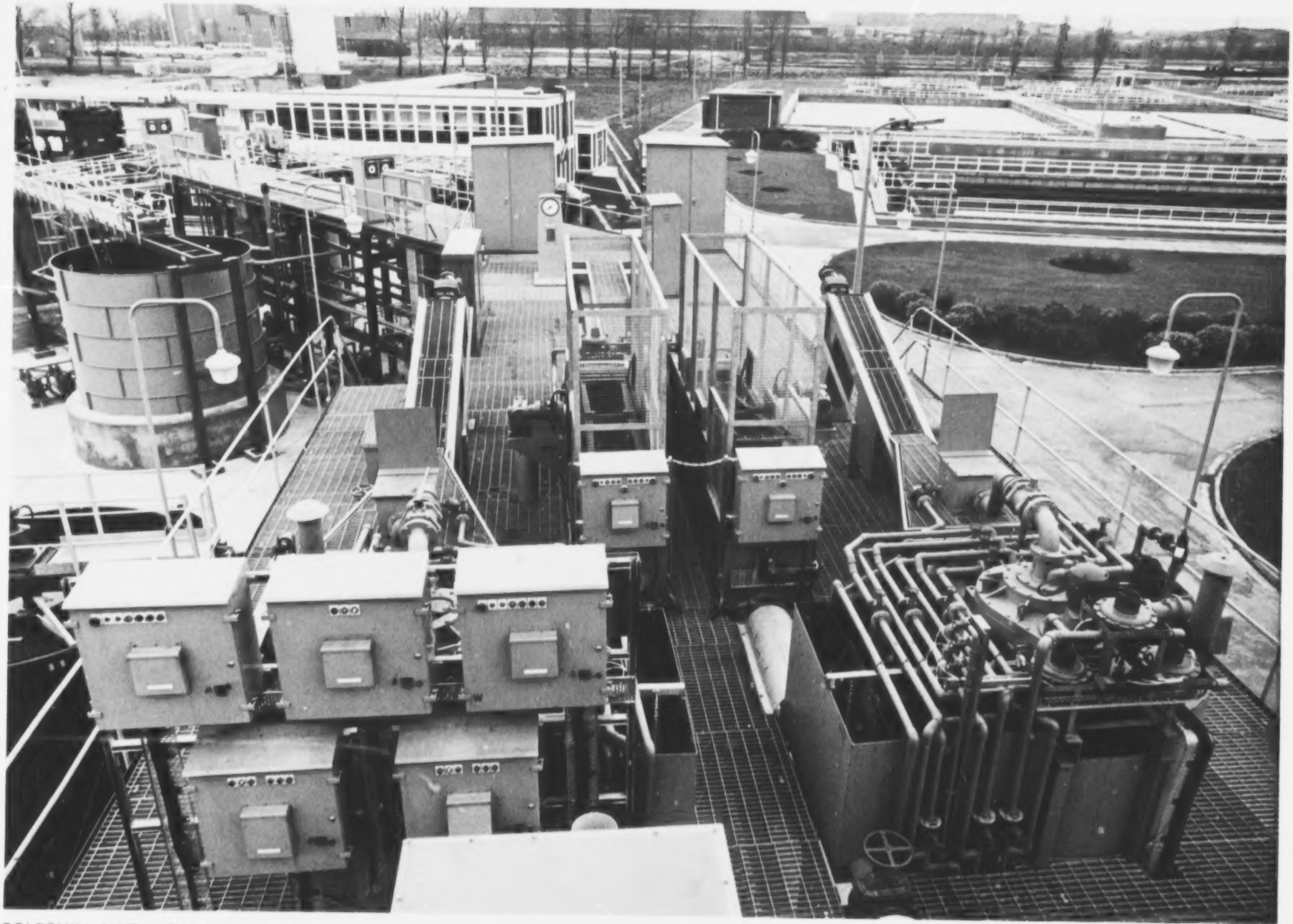

TREATMENT UNIT
GANTRY
Desludging equipment
Control panel
Mobile treatment unit (sedimentation tank) in position
3·0m
Sliding wall sections
3·0m
Piped services
Effluent drain
2·4m
Crash barrier

MOBILE TREATMENT UNIT AND TWO-STOREY GANTRY

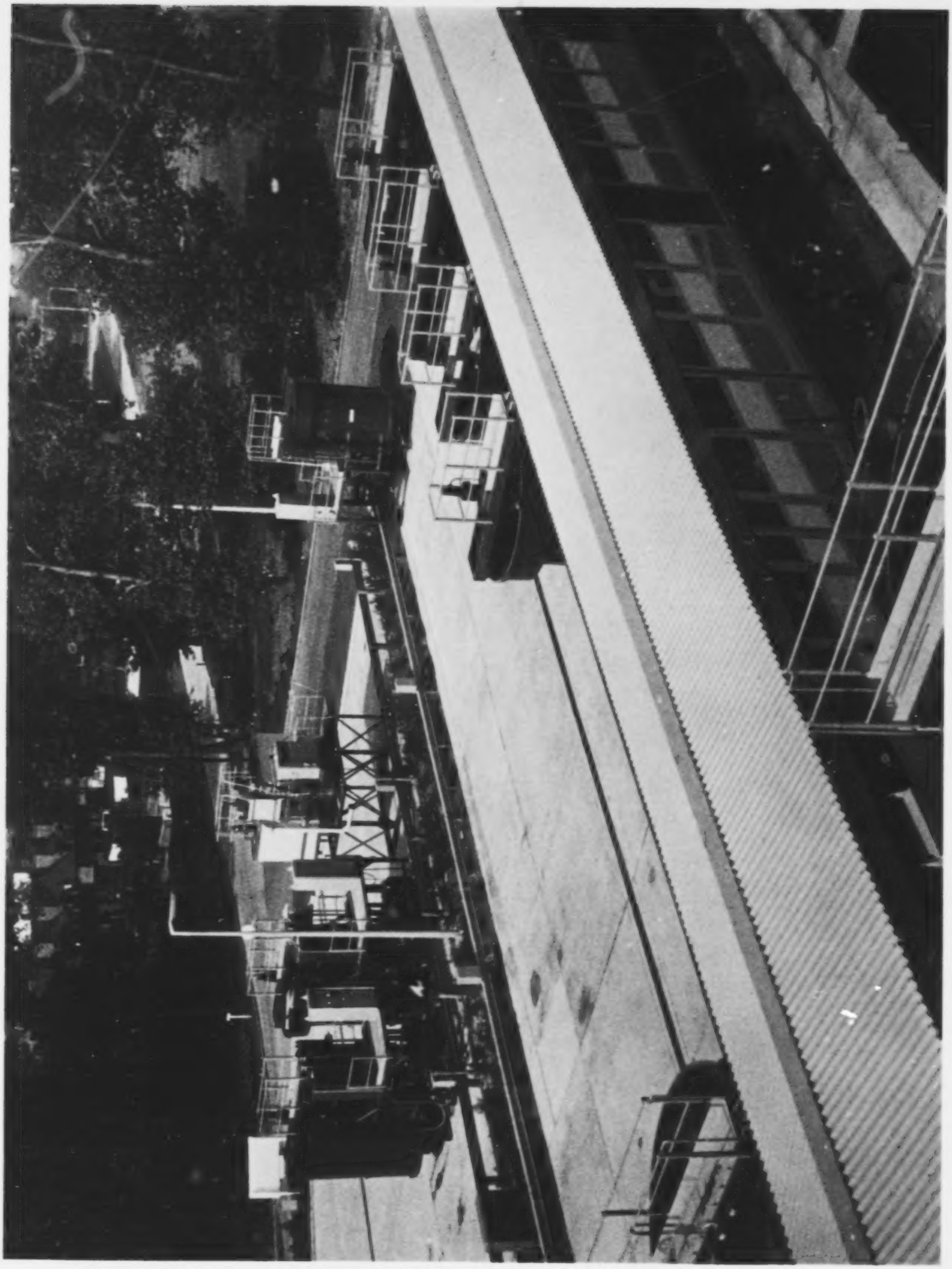
COLESHILL AWT — General Overview of Completed Works.



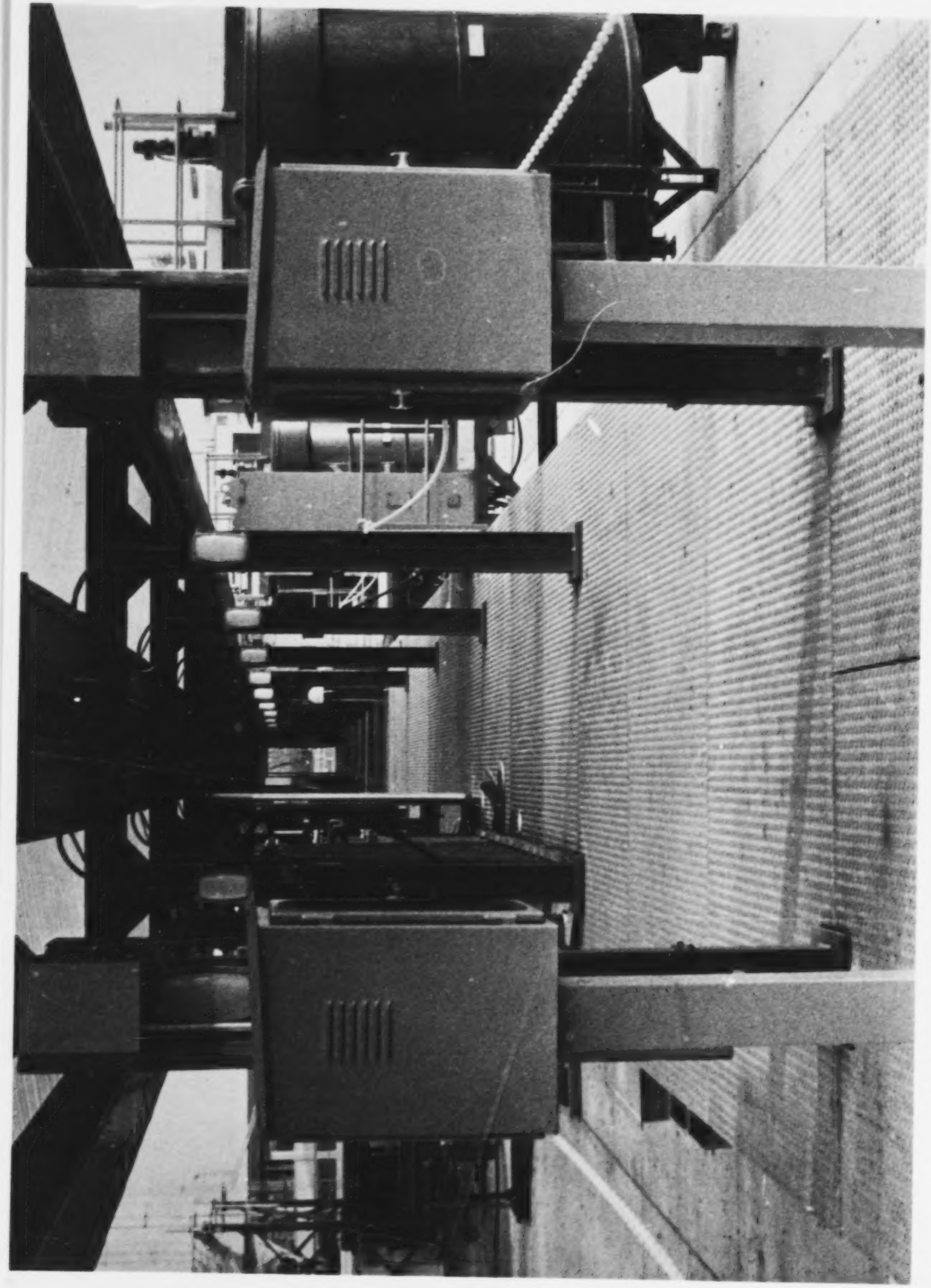
COLESHILL AWT — General Overview of Plant (under construction).



COLESHILL AWT – General View.

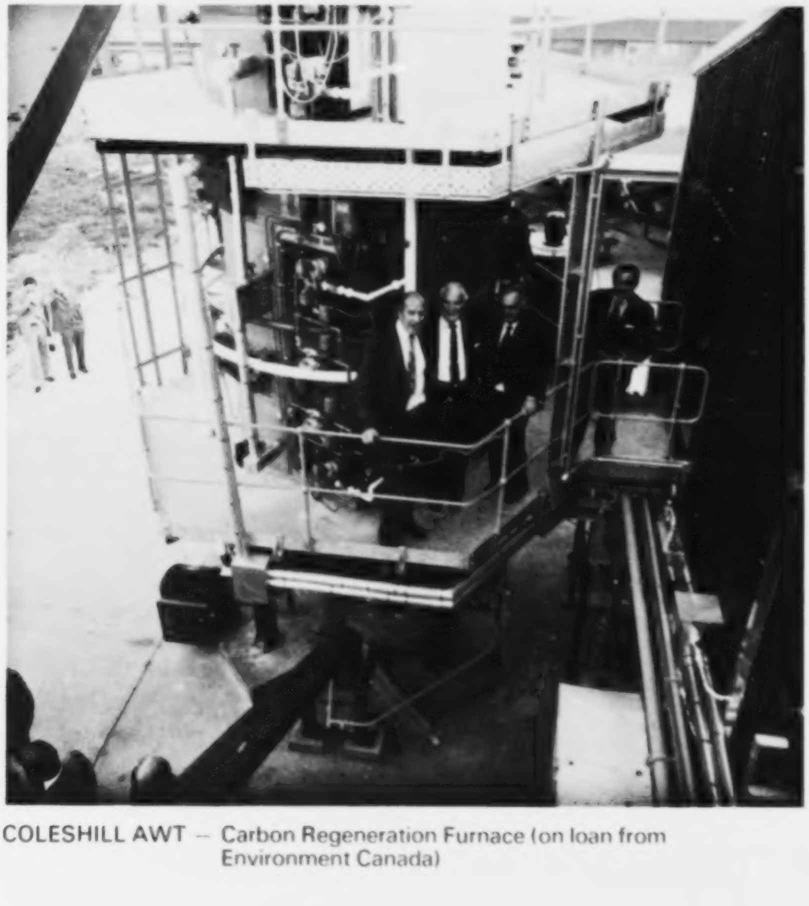


COLESHILL AWT — General View of Seven Sedimentation tanks and Lime Tank in Parking Area.



COLESHILL AWT – Process Gantry with sliding doors open looking upstream.

COLESHILL AWT – Moving Mobile Unit.



COLESHILL AWT – Carbon Regeneration Furnace (on loan from Environment Canada)

Royal Visit to Coleshill AWT
27 Feb 1976

Unveiling the plaque.

Meeting the UK AWT Committee.

United Kingdom 3

Davyhulme Advanced Wastewater Treatment Pilot Plant

General

3.1. The plant is located at the Davyhulme wastewater works of Eastern Division, North West Water Authority, serving much of Manchester.

3.2. Screened degritted wastewater is pumped from the main outfall to the works by duplicate positive-displacement pumps with individual capacity up to $18.2\text{m}^3/\text{h}$, having variable-speed controllers, and is delivered to a high-level flume recorder. The units are connected (or by-passed) by a complex system of pipes and valves which allow considerable flexibility in order of processes.

3.3. Dry weather (dwf) through these units is $147\text{m}^3/\text{d}$, normally by gravity. Flows may be either steady or varied diurnally to any required pattern within the limits 0.3 to 3 dwf. Ratings given are at dwf except where noted.

3.4. The flash mixer gives 6 minutes retention; the flocculator, provided with variable-speed paddle, gives up to 75 minutes. Lime, ferric salts, aluminium salts, and polyelectrolytes may be dosed proportional to flow; lime may also be dosed to pH control. Acid is provided for pH correction.

3.5. Four 2.2m diameter 60° conical-bottomed sedimentation tanks each have a volume of 11.25m^3, a retention of 1.5h and a surface-loading of $14\text{m}^3/\text{m}^2/\text{d}$ at maximum flow. Two may be used in parallel.

3.6. The 4.98m by 1.22m diffused-air activated-sludge tank, 2.28m in effective depth, has a capacity of 13.85m^3 and a retention of 2.33h (without allowing for the effect of returned activated sludge). There are four rows each of 22 dome-diffusers: total maximum air capacity is 220 litres/minute.

'Physical' units

3.7. Flow through these units is pumped at a steady rate of up to $109\text{m}^3/\text{d}$. Ratings given below are for that figure.

3.8. The multi-media filters (with sand and anthracite media) operate in downflow mode, with velocity 10m/h. Backwashing is automatically controlled.

3.9. Retention time in the 750mm downflow-mode column (packed with 270 kg of carbon) is 7 minutes; there is provision for backwashing.

3.10. The dry-powder feeder is rated for 0.25 to 5.0kg/h powdered carbon (dose-rates 55-1100 mg/l). Polyelectrolytes may also be dosed. The contact tank gives 0.5h retention.

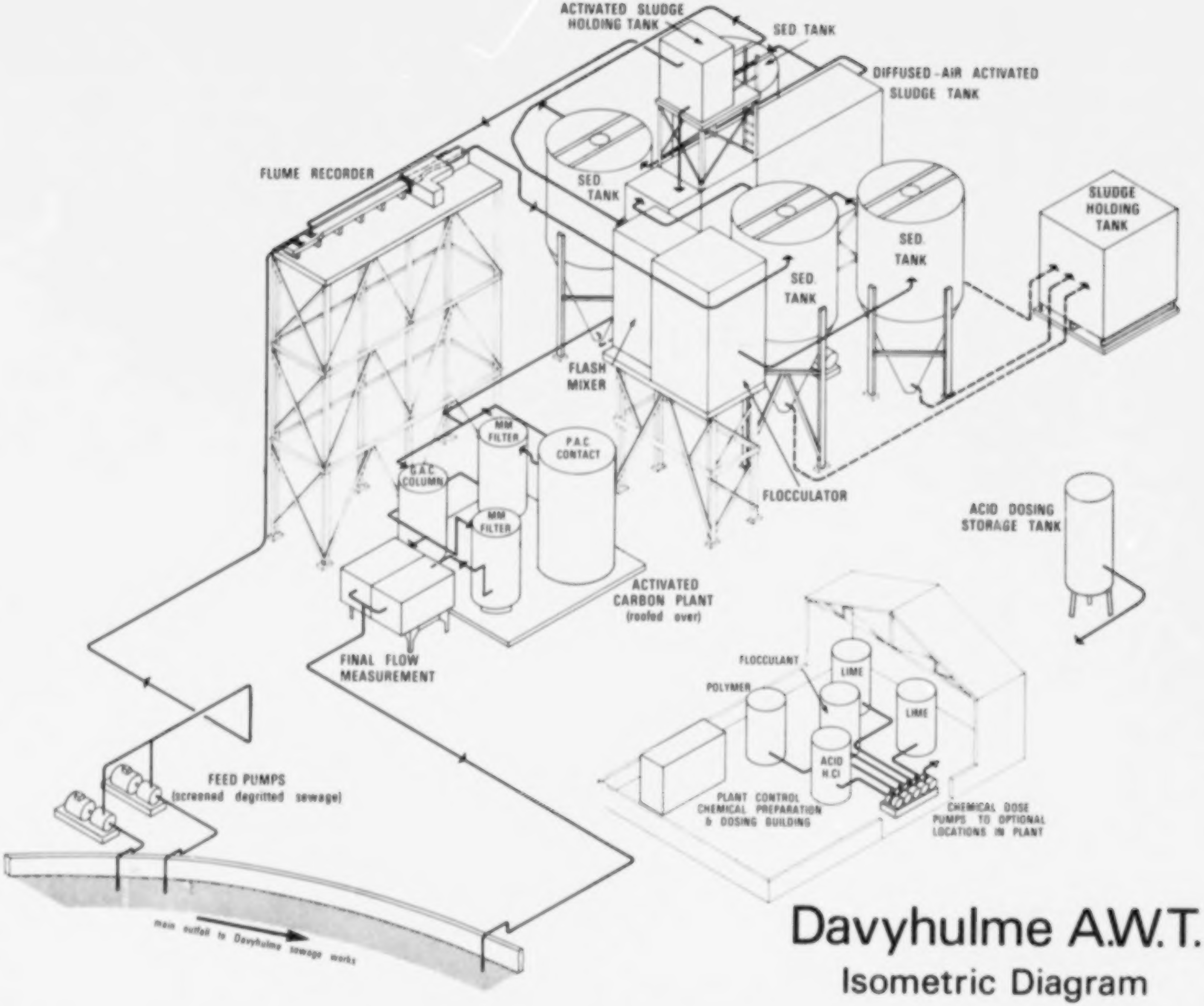
Modes of treatment

3.12. The units of the plant may be operated in the following order, giving six different modes of treatment:

Process	Mode					
	A	B	C	D	E	F
Chemical addition	1	2	1	1	1	3
Sedimentation (four tanks)	2	1	2,4	1,3,5	1,3,5	2,4
Multi-media filtration	3	3	5	6	6	5
Granular or powdered carbon adsorption	4	4	6	7	7	6
Activated sludge treatment	–	–	3	4	2	1

Staffing and laboratory facilities.

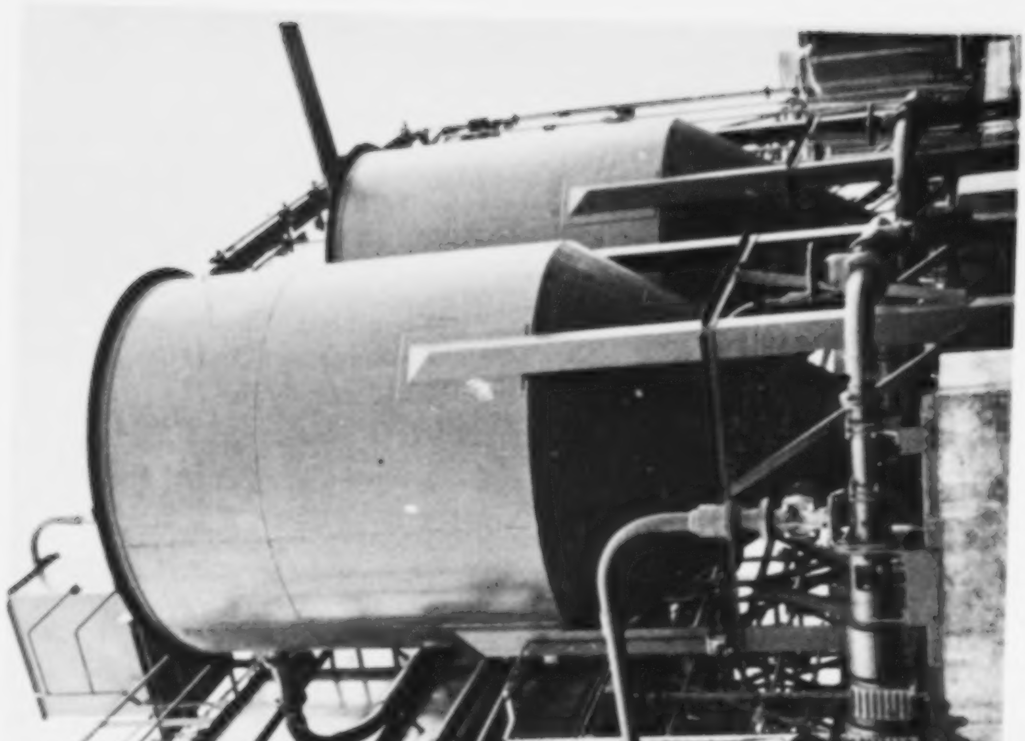
3.13. Eastern Division North West Water Authority provide a Plant Manager, staff to give continuous attendance, and laboratory facilities.


ACTIVATED SLUDGE HOLDING TANK
SED TANK
DIFFUSED-AIR ACTIVATED SLUDGE TANK
FLUME RECORDER
SED TANK
SED. TANK
SED. TANK
SLUDGE HOLDING TANK
FLASH MIXER
MM FILTER
P.A.C. CONTACT
G.A.C. COLUMN
MM FILTER
FLOCCULATOR
ACID DOSING STORAGE TANK
ACTIVATED CARBON PLANT (roofed over)
FINAL FLOW MEASUREMENT
FLOCCULANT
LIME
POLYMER
LIME
ACID H.Cl
FEED PUMPS (screened degritted sewage)
PLANT CONTROL CHEMICAL PREPARATION & DOSING BUILDING
CHEMICAL DOSE PUMPS TO OPTIONAL LOCATIONS IN PLANT
main outfall to Davyhulme sewage works

Davyhulme A.W.T.

Isometric Diagram

APPENDIX B5/3



DAVYHULME AWT — General View

United Kingdom 4

Ipswich — Physical-Chemical Treatment Pilot Plant Work at Cliff Quay Works

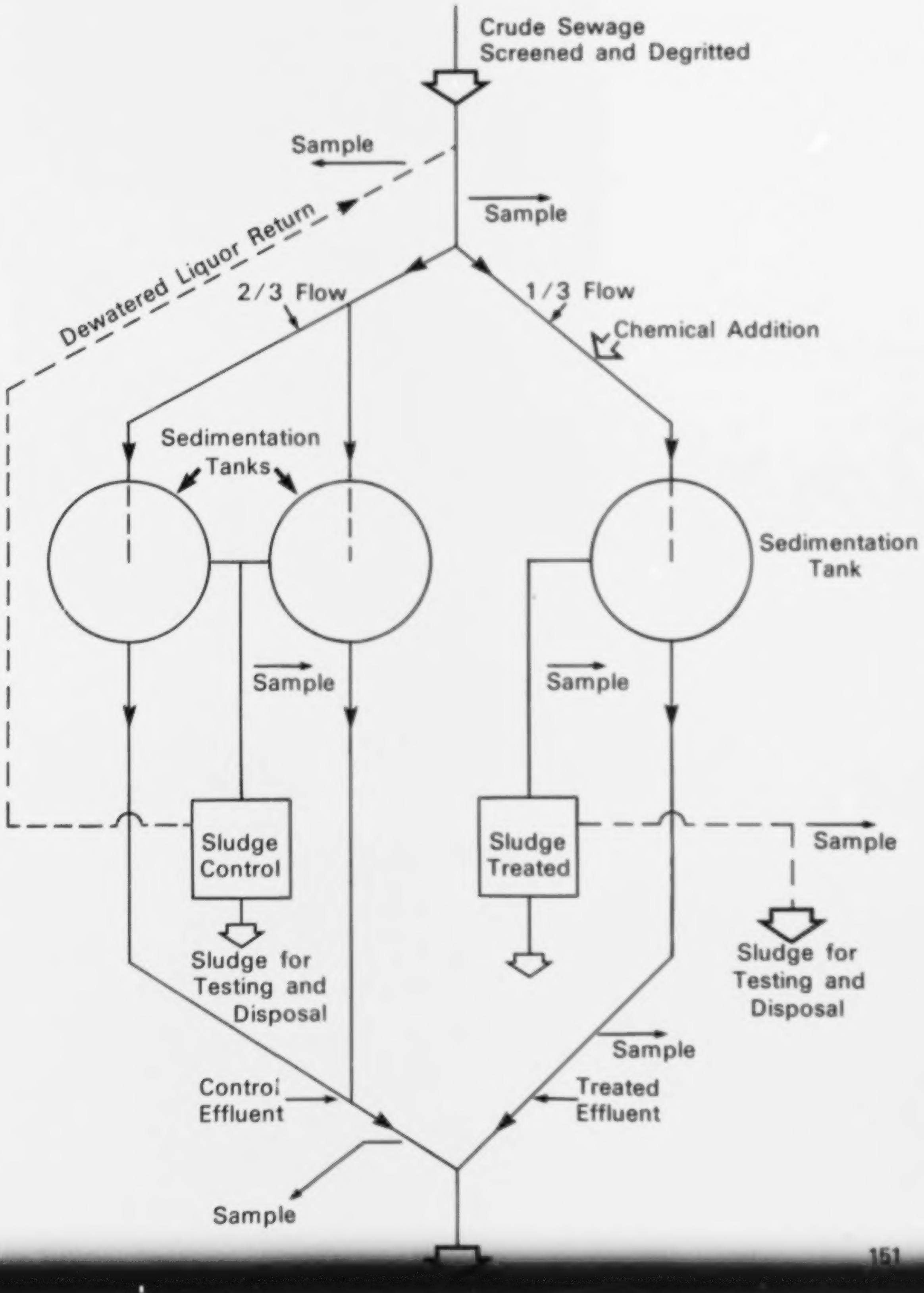
4.1. The Cliff Quay works, which serves part of the town of Ipswich, receives most of the wastewater via a semi-combined sewerage system. The works, reconstructed in 1974, comprises screens, a main lift sewage pumping station, two Dorr detritors, six circular scraped sedimentation tanks with a present retention time of nine hours, three rectangular storm water tanks and a pumping station to lift sludge to a jetty from where it is shipped for sea disposal. The works which is under the control of the Anglian Water Authority, is situated down stream of the town's suburban development and discharges into the River Orwell. Biological treatment was considered for two thirds of the flow after primary sedimentation and mixing with the remaining third before discharge to the estuary but this proposal was deferred because of financial restrictions.

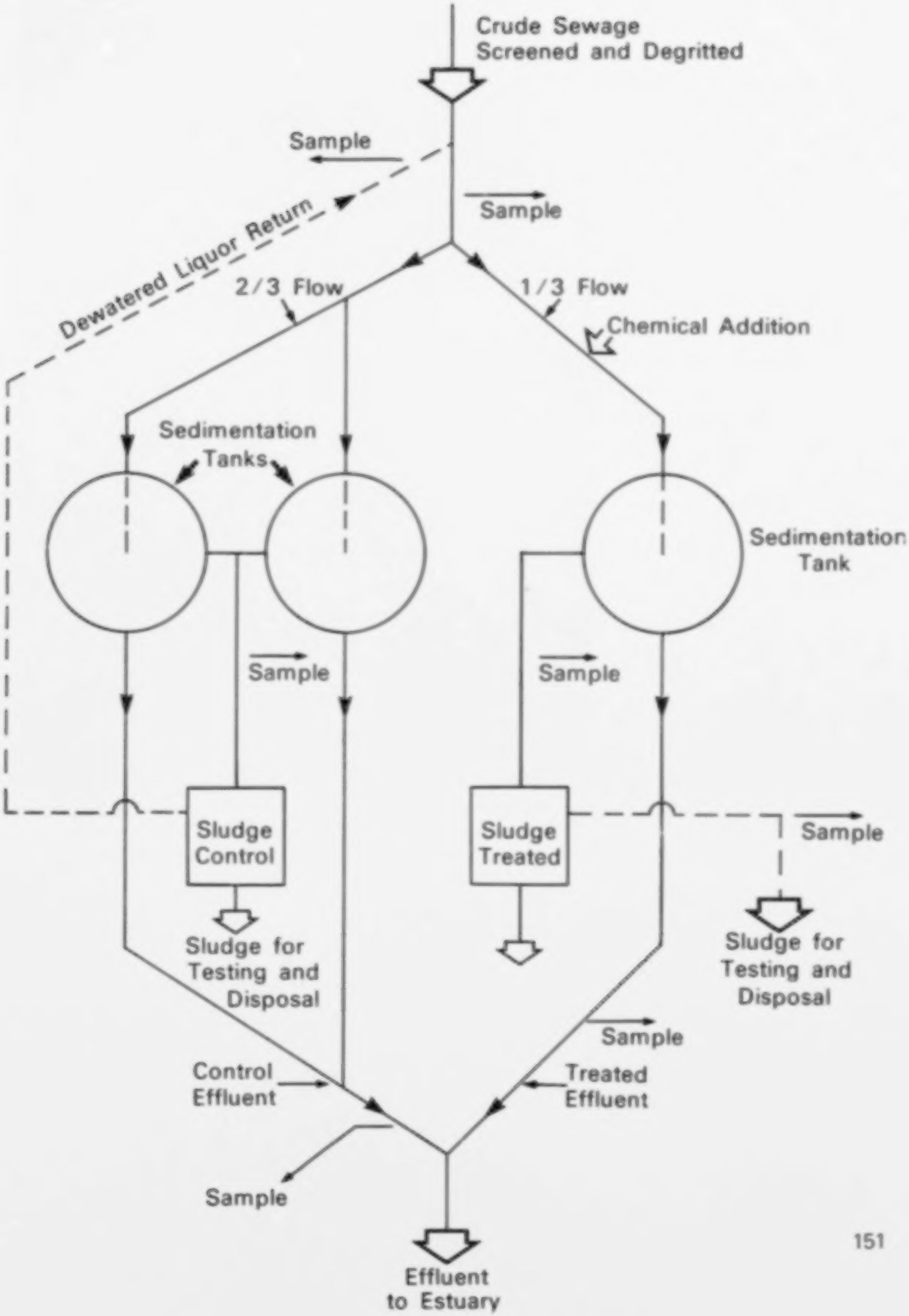
4.2. Because of its layout the Cliff Quay works was selected for a programme of studies of physico-chemical treatment as a method of partial treatment of crude wastewater. The works was designed to treat 36,000 m^3/d dwf but receives 29,000 m^3/d average flow at present. The sedimentation tanks are arranged so that one pair is fed by a long channel, the remaining four by a short channel. For the purposes of the investigation only half the capacity of the works is utilized ie one tank of the pair fed by the long channel being used for chemically treated wastewater and a pair of the tetrad being used as a control and fed by the short channel. The flow is divided by a proportioning flume so that one third is chemically treated whilst the remaining two thirds of flow is used as a control.

4.3. It is intended to investigate the use of chemically aided settlement as a means of partially purifying wastewater to achieve a quality acceptable for discharge to estuarial and coastal waters, and further to determine the dosage of various chemicals necessary to achieve, after primary sedimentation, an effluent quality of 140 mg/l BOD and 70 mg/l SS, such that the operation of the plant, including the characteristics of the sludges produced are optimised. The chemicals to be used in the experiment are lime, ferric sulphate, cationic polytelectrolyte and aluminium sulphate as a primary coagulant followed by a polyelectrolyte to achieve secondary flocculation. In addition to the determinands in the effluent quality specification, a number of other determinands have been monitored in the crude, control and treated wastewater eg, COD, Nitrogen, Chloride, Phosphate, Sulphate, pH, Redox Potential and some metals. A further objective is the study of the effect of such treatment on the volume and characteristics of the sludges produced.

4.4. Work on this project has been in progress for over twelve months and comprehensive results are available.

The Cliff Quay Wastewater Treatment Works Diagrammatic Experimental Arrangements


Crude Sewage
Screened and Degritted
Sample
Sample
Dewatered Liquor Return
2/3 Flow
1/3 Flow
Chemical Addition
Sedimentation
Tanks
Sedimentation
Tank
Sample
Sample
Sludge
Control
Sludge
Treated
Sample
Sludge for
Testing and
Disposal
Sludge for
Testing and
Disposal
Sample
Control
Effluent
Treated
Effluent
Sample



Crude Sewage
Screened and Degritted
Sample
Sample
Dewatered Liquor Return
2/3 Flow
1/3 Flow
Chemical Addition
Sedimentation
Tanks
Sedimentation
Tank
Sample
Sample
Sludge
Control
Sludge
Treated
Sample
Sludge for
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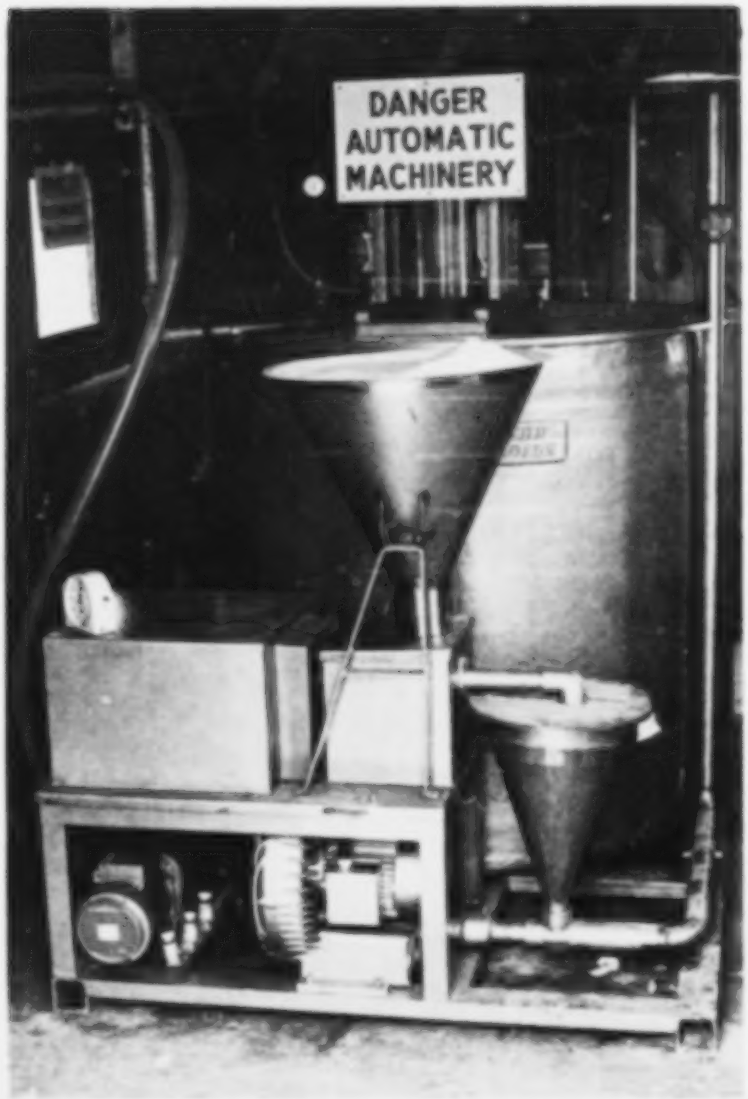
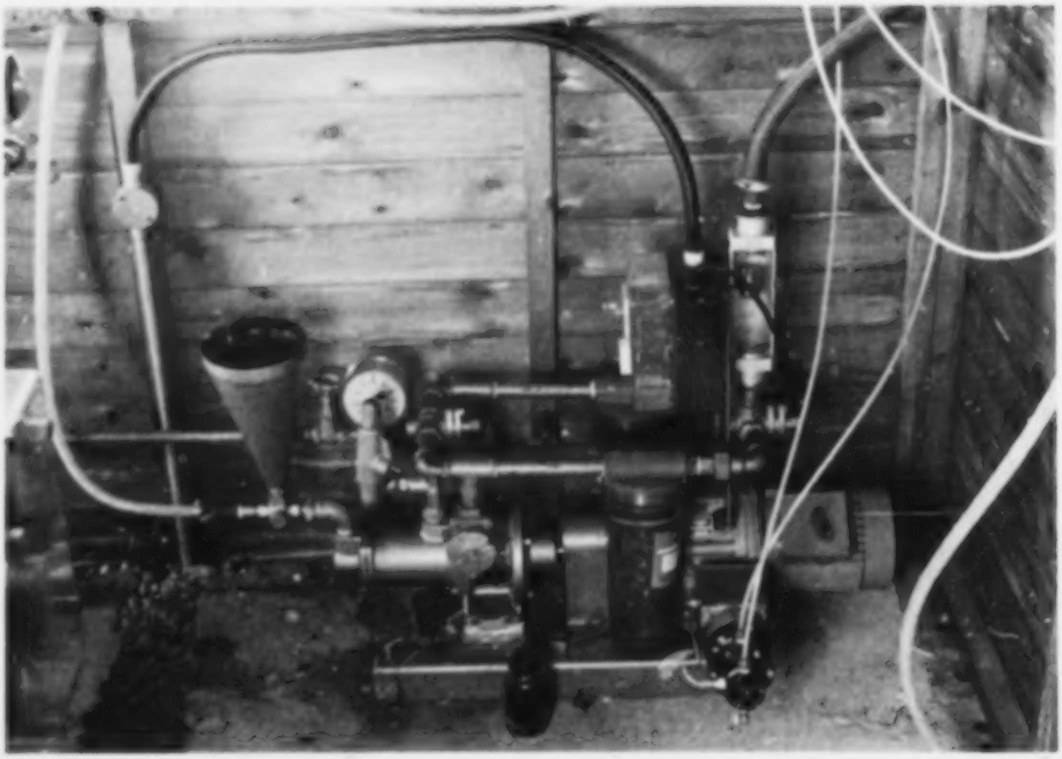
Disposal
Sludge for
Testing and
Disposal
Sample
Control
Effluent
Treated
Effluent
Sample
Effluent
to Estuary


DANGER
AUTOMATIC
MACHINERY

ANGLIAN WATER AUTHORITY – Cliff Quay
Automatic Polymer dissolving unit showing the feed hopper.



ANGLIAN WATER AUTHORITY:
Cliff Quay sewage treatment works, Ipwich.
Polymer solution storage tank and dosing pump.

United Kingdom 5

Stevenage Advanced Wastewater Treatment Pilot Plant

General

5.1. The plant is located at the Stevenage Laboratory of the Water Research Centre (WRC) and run by the Laboratory's staff. The feed is screened degritted wastewater from a branch sewer from Stevenage New Town.

Chemically-aided settlement

5.2. The steady flowrate through these units is 41m^3/d. The flashmixer has a retention of 1 minute. Chemical dosage can be controlled by pH (where appropriate) or flowrate. There is a flocculation with 32 minutes retention and an alternative 4 compartment tank with 8 minute retention; paddles are variable speed. The conical-bottomed sedimentation tank has a volume of 1.7m^3 and a retention of 1 hour. Sludge is recycled by positive displacement pump.

Recarbonation columns and tanks

5.3. The steady rate of flow through these units is 16.2m^3/d. There are two columns with 8 minutes retention, with an intermediate sedimentation tank having 1 hour retention. Sludge is recycled from the base of the tank. Carbon dioxide dosed to each column is controlled by pH.

Mechanical filtration and carbon adsorption

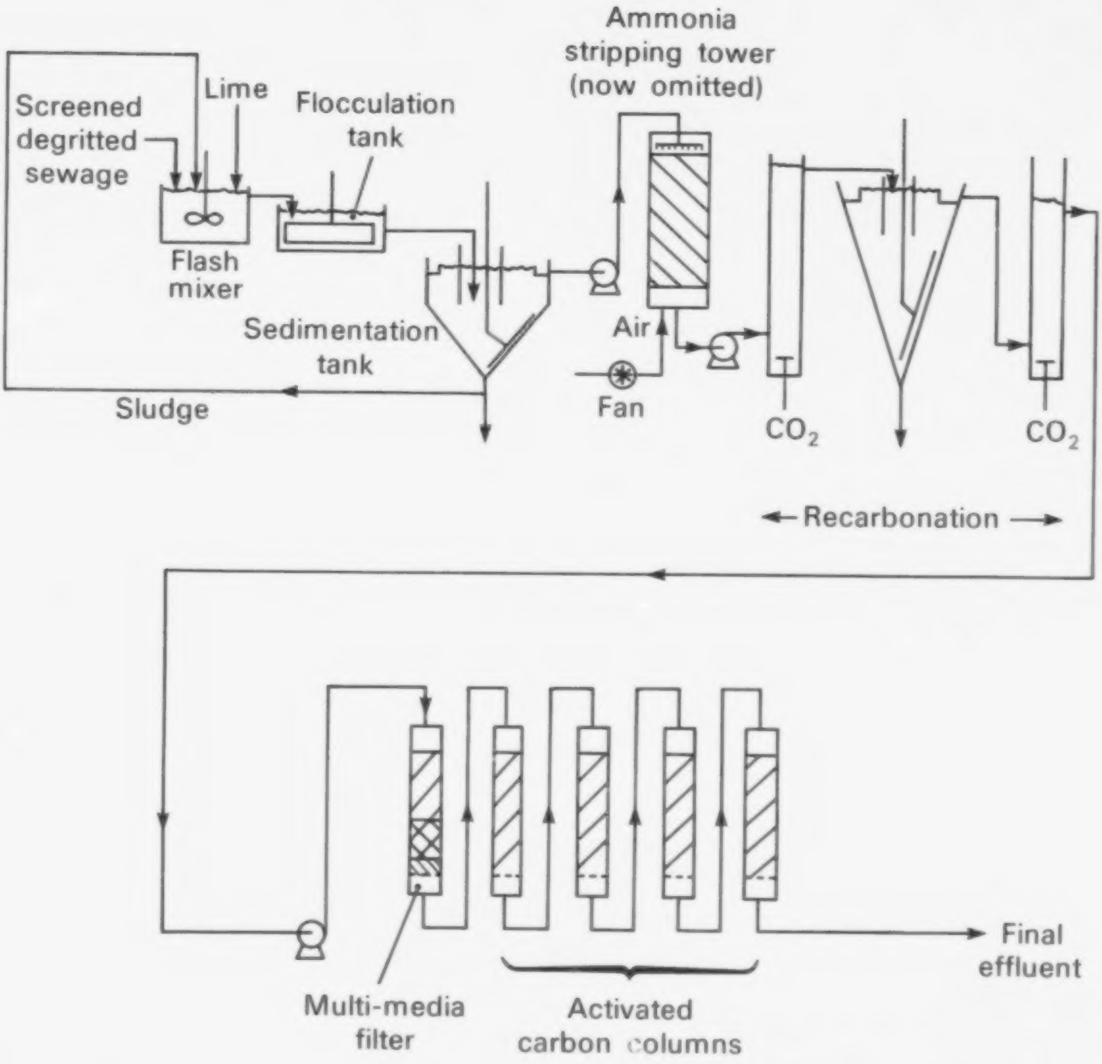
5.4. Flowrate through these units is normally 7.2m^3/d. The multi-media filter (containing sand, anthracite and garnet) operates in downflow mode, with velocity normally 9.6m/h. Backwashing and air scour are controlled manually. The five granular activated carbon columns (each packed with 30 litres of carbon) can operate in upflow or downflow mode; retention is normally 0.5 hours. There is provision for backwashing.

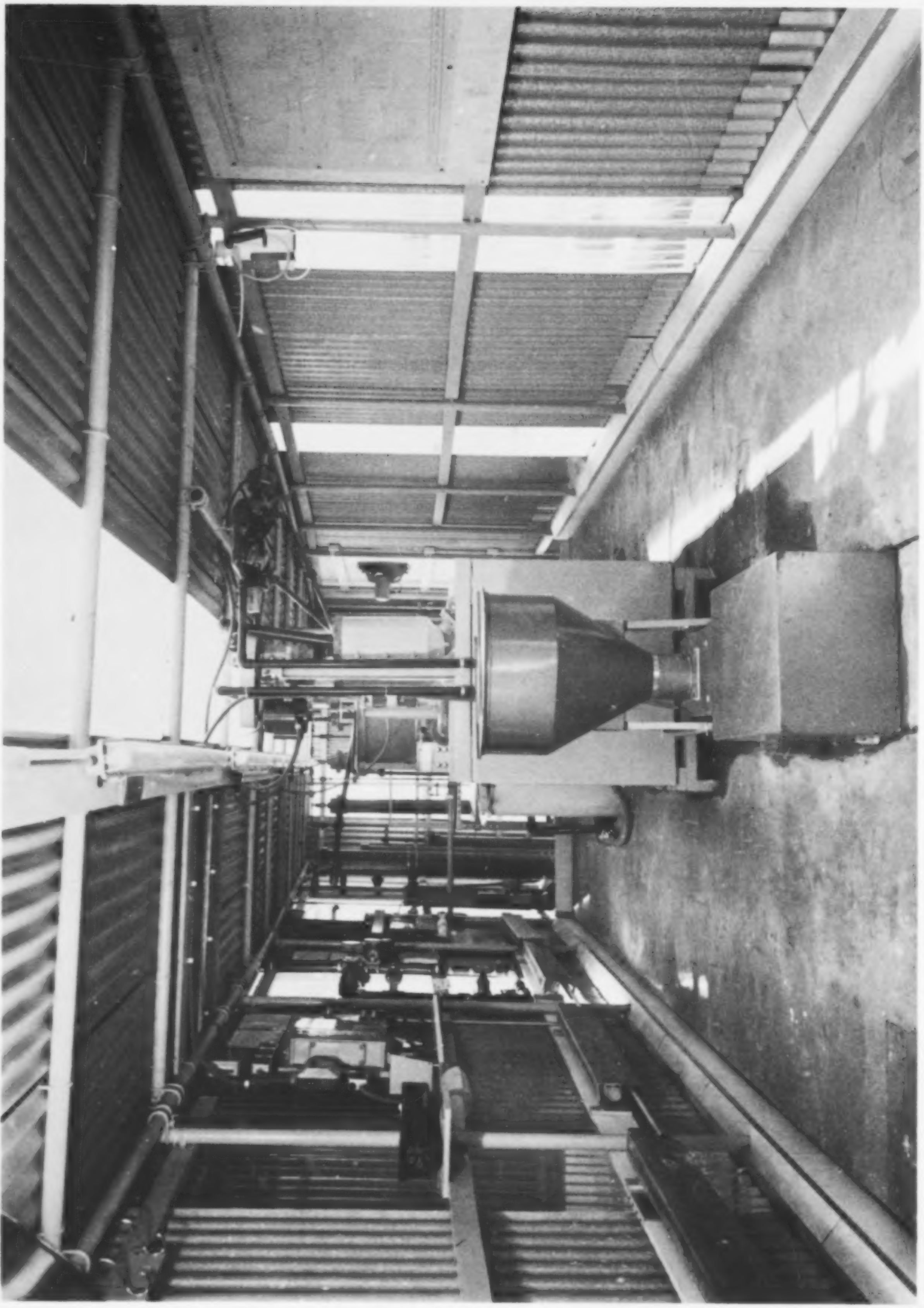
Nitrification/denitrification sidestream

5.5. The steady flow through these five units can be set at any rate up to 3.6m^3/d (150 litres/h). Feed is chemically-aided settlement effluent from the sedimentation tank of the main unit. Nitrification is performed in a fully mixed 450 litre diffused air activated sludge tank with 3 hour net retention; sludge is recycled to the latter from a 285 litre secondary sedimentation tank with 1.9 hours retention. Denitrification, by the anoxic activated sludge process, is performed in a 130 litre stirred tank dosed with methanol, giving 0.87 hours retention. Denitrified effluent is re-aerated in a 120 litre diffused air tank with 0.8 hours retention, and settled in a 200 litre final tank giving 1.33 hours retention.

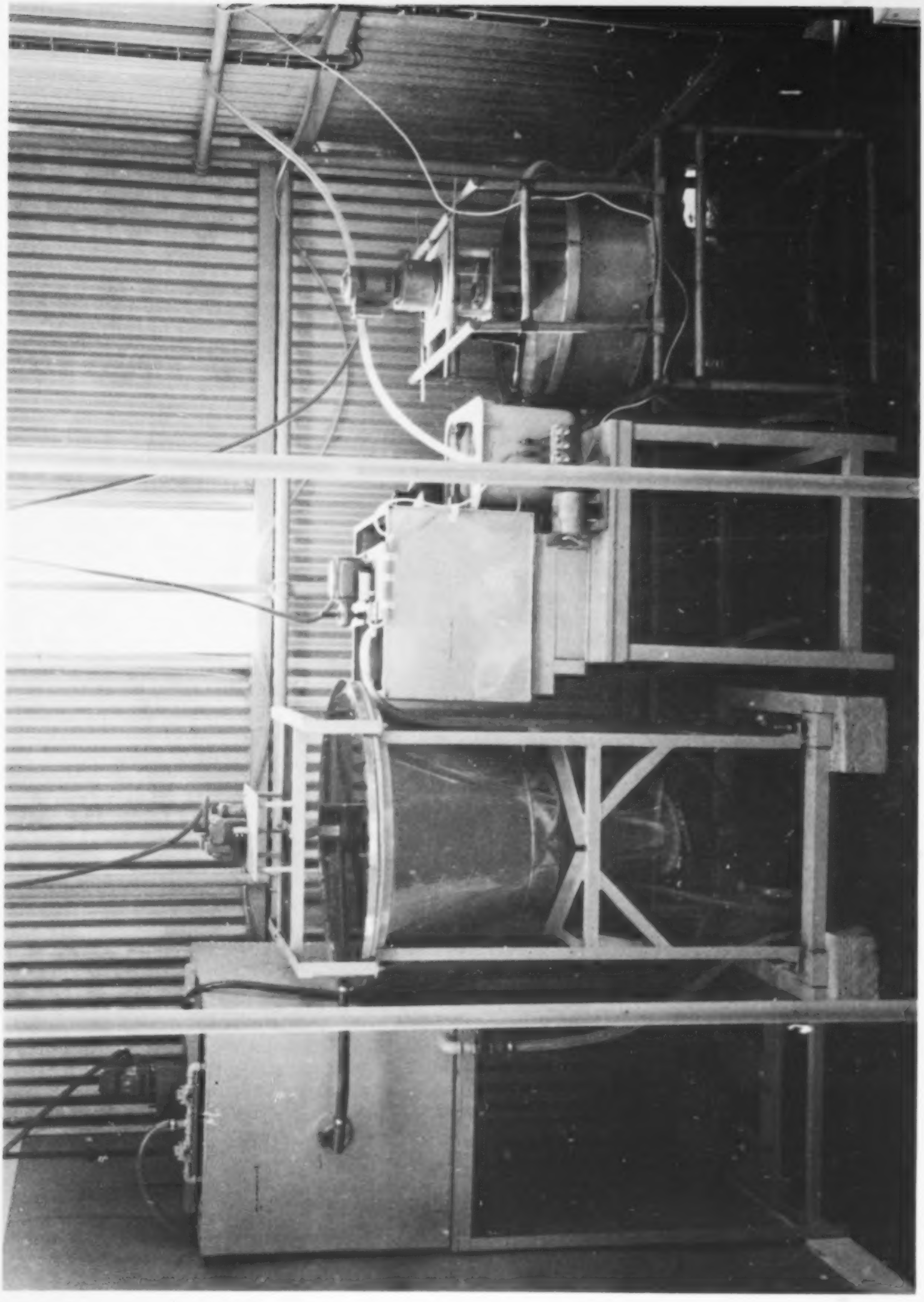
5.6. The plant was designed and built by the Department's Water Pollution Research Laboratory, predecessors to WRC.

Stevenage Pilot Plant
Main Stream Flow Diagram


Ammonia stripping tower (now omitted)
Screened degritted sewage
Lime
Flocculation tank
Flash mixer
Sedimentation tank
Air
Fan
Sludge
CO_2
CO_2
Recarbonation
Multi-media filter
Activated carbon columns
Final effluent



STEVENAGE AWT — General View.



STEVENAGE AWT

United Kingdom 6

6. Palmersford Wastewater Treatment Works

6.1. The Palmersford Works which is under the control of the Wessex Water Authority, is the first full scale municipal plant in this country to utilise high purity oxygen in the main activated sludge process. It is based on the Unox system.

6.2. The extension takes the form of a two-stage activated sludge plant and both stages employ surface aeration, the first being in an enclosed atmosphere of high purity oxygen. The effluent standard from the extension is required to be better than 15:10:10 (mg/l SS:BOD_5:AmmN). The first (oxygen) stage is capable of treating to a 30:20 standard and the second (air) stage achieves nitrification.

6.3. A Unox pilot plant was operated early in 1975 at the works on settled and crude sewage with retention times varying between 0.75 hours and 1.6 hours (first stage) and 1.7 hours and 3.2 hours (second stage). Throughout the phase of operation which most closely related to that of the full scale plant the effluent quality averaged 5:5:1 (mg/l SS: BOD_5: AmmN).

6.4. The present works employs conventional biological filtration with recirculation and the extension forms a separate parallel works with a possible link to the existing filters after the first (oxygen) stage tanks. It is therefore possible for nitrification to be achieved either by filtration or by the 2nd stage activated sludge plant. There is considerable interest in the new plant and the design has allowed for a high degree of flexibility to permit research to continue into this form of treatment. For example, the new plant is capable of division into two identical halves to allow operation of one stream to be varied outside normal design limits whilst maintaining the operation of the other stream as a control.

6.5. The plant will be virtually fully automatic in its operation incorporating variable control of the returned activated sludge on each stage, automatic control of the rate of aeration in the second stage by dissolved oxygen monitoring and automatic flow balancing facilities.

6.6. The first (oxygen) stage is operated by pressurising the gas space above water level with high purity oxygen and oxygenation is achieved by conventional mechanical aerators operating through the roof of the tank. Oxygen is produced in a Wimpey Unox Pressure Swing Adsorption Unit adjacent to the first stage tanks. Air is compressed, cooled, dewatered and passed into one of the beds of molecular sieve material where nitrogen is adsorbed. Three beds are used in sequence to maintain the flow of oxygen while regeneration of the sieve material takes place. Standby liquid oxygen storage is provided which is also used to meet peak load requirements. The process design for this section of the works is based on the Unox process developed in the United States where it is now extensively used but it is thought to be the first time this particular process has been used in Europe. Benefits claimed for the system when compared with conventional activated sludge plants, include less space requirements, lower sludge production and lower capital cost.

7. The Palmersford Works is providing a unique opportunity for the study of the use of oxygen in the treatment of municipal sewage in direct comparison with more traditional methods.

8. Space is available between the existing and new works for duplicating the new works in the future.

Technical Information

Existing Works

Effluent Standard — 30:20(mg/l SS: BOD)

Design — 2,300 m^3d (27 l/s)

Design Population — 10,000 - 12,000

New Works

Effluent Standard (1st Stage) — 30:20 (mg/l SS: BOD)

(2nd Stage) — 15:10:10: (mg/l SS:BOD:AmmN)

Design DWF — 4,500 m^3/d (52 l/s)

Design Population — 20,000 - 24,000
Max flow to works — 6 DWF

Max flow to full treatment — 3 DWF

PSA Oxygen Generator

		Feed	*Product*	*Waste*
Average flow rate at STP (m^3/h)		87	6.5	80.5
Pressure	(psig)	40	2.5	1
Temp	(^oC)	35	35	27
Composition	(mole %)			
Nitrogen		78	6	84.6
Oxygen		21	90	14.7
Argon		1	4	0.7
Water		100% RH	1 ppm	50% RH
CO_2		360 mg/l	1 ppm	400 mg/l

Output	1.1 tonnes oxygen per day (present)
	1.8 tonnes oxygen per day (ultimate)

Main Contractors

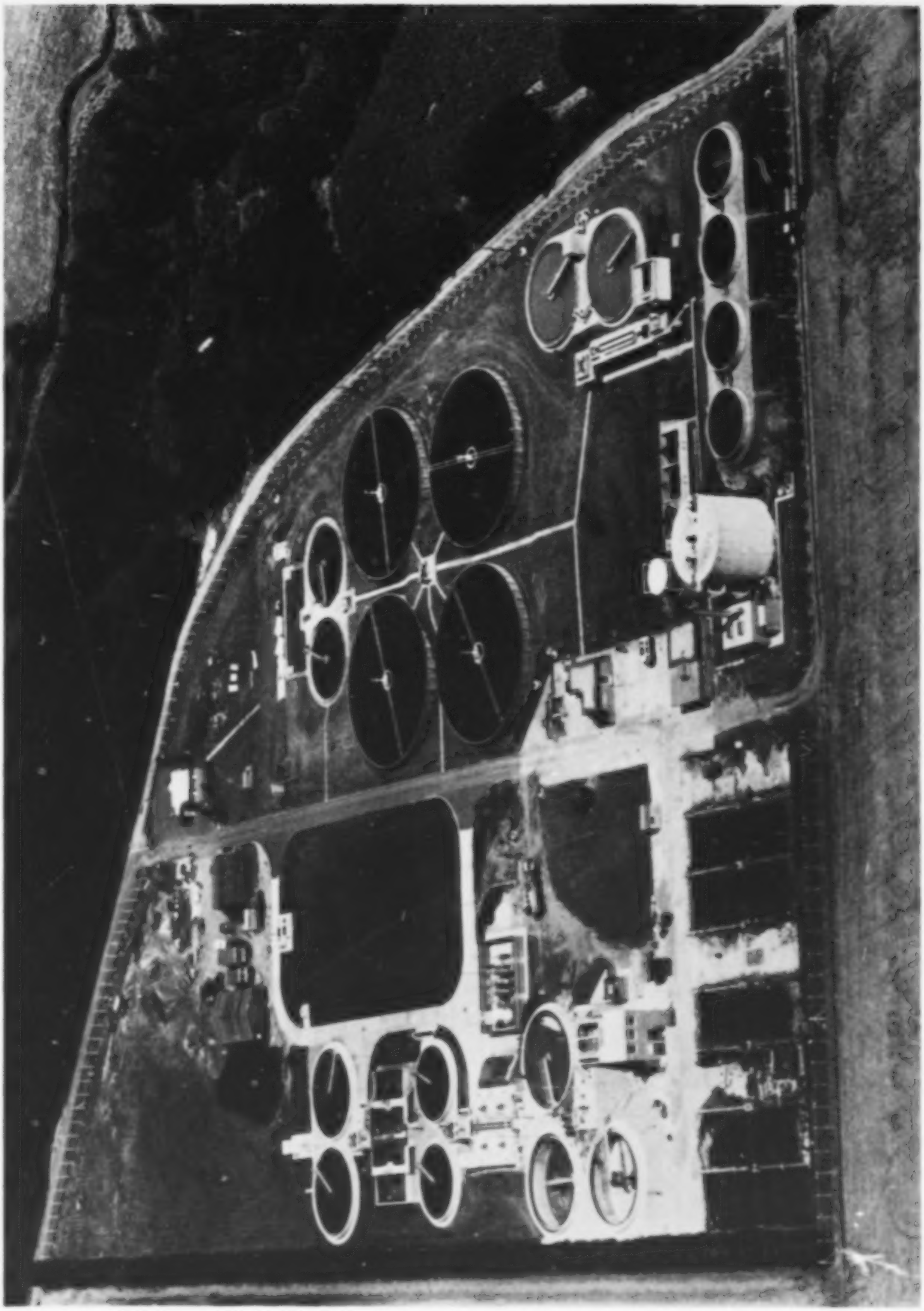
Consulting Engineers	— J D and D M Watson
Civil Engineering Works	— Southern Counties Construction Co. Ltd.
Unox System — PSA Oxygen	— Wimpey Unox Limited
Generator & 1st Stage Process	
Equipment	
Screens, Grit Channel Aeration	— Ames Crosta Limited
Screw Pumps, Scrapers, 2nd	
Stage Aerators	
Grit Pumps and Classifier	— Wallwin Pumps Limited
Ram Pumps, Washwater System	
Decanting and Auxiliary Pumps	
Electrical Engineering	— Southern Electricity Board

Treatment Unit Characteristics

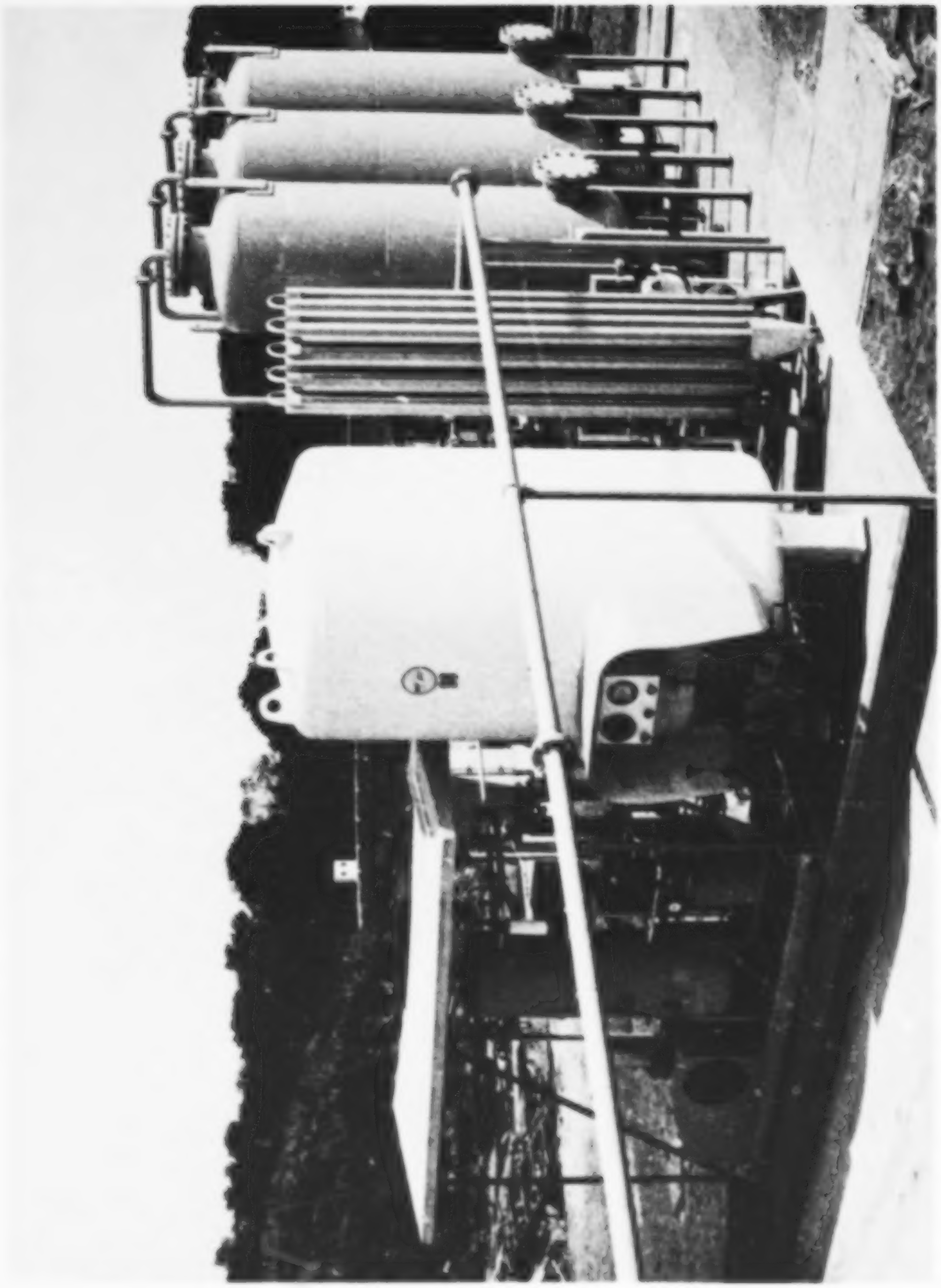
New Works

Inlet Works	— Designed to accept 6 DWF to the works, with allowance for duplication of the new works.
Screens	— 2 No mechanically raked, 20 mm spaces, automatic operation.
Grit Channel	— 2 No spiral flow aerated channels. Classified grit is disposed to tip with screenings.
Primary Sedimentation Tanks	— 1 or 2 No circular tanks with blade scapers. Max upward flow rate 3.6 or 1.8 m/h. Automatic withdrawal of sludge via ram pump.
Storm/Balancing Tanks	— 1 or 2 No circular tanks. Flow automatically returned for treatment. Excess overflow to river.

1st Stage Tanks	– 4 pocket covered aeration tanks divided into two parallel streams. Total retention is 1.76 hrs at DWF. 4 No 4.5/3 kw two speed aerators.
1st Stage RAS	– 2 No 700 mm dia screw pumps 90 1/s each max capacity. Rate of flow automatically varied.
1st Stage SAS	– 2 No positive displacement pumps – automatic operation.
Intermediate Settlement Tanks	– 2 No circular tanks with chain scrapers. Max upward flow rate 3.0 m/h. Automatic sludge withdrawal.
2nd Stage Tanks	– 2 pocket open aeration tank divided into two parallel streams. Total retention 3.0 hrs. at DWF. 2 No two speed aerators, immersion depth automatically controlled by reference to dissolved oxygen levels.
2nd Stage RAS	– As 1st Stage.
2nd Stage SAS	– Manually withdrawn – very small quantity.
Final Tanks	– 2 No circular tanks with chain scrapers. Max. upward flow rate 1.8 m/h. Automatic sludge withdrawal.
Sludge Treatment	– Surplus sludge is pumped to the existing consolidation tanks or returned for co-settlement with the primary sludge. Sludge is digested prior to liquid disposal to adjacent land.
PSA Plant	– Standard design capable of 1.8 tonnes oxygen per day. Present production 1.1 tonnes per day. 1 No 37 kW main compressor feeding 3 No molecular sieve vessels. Pneumatic controls supplied by 2 No 12.5 kW compressors (1 + standby). Oxygen storage vessel 3.7 tonnes capacity.
Standby Power	– 1 No skid mounted 200 kVA diesel alternator set with automatic mains failure changeover.



WESSEX WATER AUTHORITY — Palmersford Works: Aerial View.



WESSEX WATER AUTHORITY — Palmersford Works. PSA Oxygen Manufacturing Plant.

PLANT DETAILS

APPENDIX B6

APPENDIX No.	TITLE
B6	UNITED STATES
B6/1	United States 1 – Minnesota – Rosemount Advanced Wastewater Treatment Plant.

United States — 1

Minnesota — Rosemount Advanced Wastewater Treament Plant

Introduction

1.1. The Rosemount Advanced Wastewater Treatment Plant is classified as an independent physical-chemical treatment (IPCT) plant. The facility treats domestic wastewater employing strictly physical and chemical processes. Rosemount is the first full-scale plant of its kind to be placed in operation in the United States. It is the first facility to treat raw wastewater by IPCT from beginning to end. Previously physical-chemical processes were applied to effluents from biological treatment plants. The plant was designed to meet future "no pollutional discharge" standards. The designed conditions are listed in Table 1. The plant consists of two process trains which are, with the exception of the chlorination unit, in parallel. A flow diagram of the plant is shown in Figure 1. The plant was put into service November 19, 1973, and has been in service continuously since that time.

Plant Performance

1.2. The data presented in this report were obtained primarily during the period June 1975 — May 1976. During this period, the sewered population of Rosemount was around 3000 with an average raw sewage flow of 871 m^3/d. The industrial flows averaged 52 m^3/d and consisted mostly of municipal sewage. The average mg/l of BOD_5, COD, suspended solids, NH_3-N and P in the raw wastewater were 230, 570, 270, 37 and 13 respectively. After the initial difficulties associated with start-up and shakedown, the plant has produced a high quality effluent. The plant performance data are summarized in Table 2.

1.3. During the first two years of operation, hydrogen sulphide generation in the carbon columns caused odour and corrosion problems. Although daily backwashing the column reduced the amount of hydrogen sulphide produced, it was still a problem. Early in 1976, the system was modified so that sodium nitrate could be fed to the carbon column influent. Based on the experience to date, it appears that hydrogen sulphide generation can be controlled by daily backwashing and the addition of 5 mg/l of sodium nitrate as N. The backwash flow averaged 10.8% of the raw flow.

1.4. The practical NH_3-N exchange capacity of the zeolite, clinoptilolite, is a function of the regeneration condition, the NH_3-N concentration applied, and the competition from other irons such as potassium, calcium and magnesium. During the period of June 1975 through July 1976, several regeneration schemes were utilized. The effectiveness of regeneration increases as the pH of brine solution used to regenerate the zeolite is increased. The NH_3-N removal efficiencies averaged better than 80% when regenerations were conducted at pH 13. However, the cost associated with pH control becomes prohibitive for high pH regenerations. Two factors prevented the obtaining of an effluent limit of 1 mg/l N. The ion exchange system design was based on an NH_3-N concentration of 15 in the raw wastewater; whereas, the actual concentration was 39 at the time the plant was put in service. Secondly, because of physical constraints it was not possible to conduct two complete regeneration-strip cycles per day.

1.5. The Rosemount plant served to identify certain difficulties in designing and operating IPCT plants. The experience gained provided guidance on how to avoid these difficulties and changes to make to reduce energy and chemical cost.

1.6. Much has been learned about sizing clinoptilolite systems and alternate methods for regeneration. Two of the largest municipal wastewater installations under construction in the USA which will use clinoptilolite are the Upper Occoquan in Virginia (0.66 m^3/s) and the Tahoe-Truckee in California (0.26 m^3/s). Both of these plants will use 2% soldium chloride solution near neutral pH. Although greater regenerant volumes are required than with a high pH regenerant (10-30 bed volumes), this is not a major disadvantage if the regenerant is recovered and reused in a closed loop system.

Table 1 – Design Criteria

Design Year	1978-1981
Equivalent population	7,000
Wastewater Flow, m^3d:	
Average Annual	2270
Peak	4540
Average raw wastewater characteristics, mg/l:	
BOD_5	240
COD	525
Suspended Solids	300
Total Phosphorus	10
Total Kjeldahl Nitrogen	25
Alkalinity, as $CaCO_3$	350
Limiting effluent quality, mg/l:	
BOD_5	10
Suspended Solids	10
Total Phosphorus	1.0
Ammonia Nitrogen	1.0
pH, units	8.5
Faecal Coliforms, MPN/100 ml	200

Parshall flume (1):	
Throat Width, mm	152
Mechanically-cleaned bar screen (1)	
Width, meter	1
Bar Opening, mm	25

Note: Number in 'parenthesis' is the number of units or systems.

Raw wastewater pumps, Variable Speed (3)	
Capacity of each, l/s	28

Each Process Train

Solids Contact Clarifier (1):	
Detention Time, hours	3.8
Overflow Rate, $m^3/m^2.d$	24
Weir Loading Rate, $m^3/m.d$	52
BOD_5 Removal, %	80
Suspended Solids Removal, %	95
Total Phosphorous Removal, %	90
First dual media filter (2):	
Filtration Hydraulic Rate, $l/m^2.s$	1.4
Backwashing	
Air Scour Rate, $m^3/m^2.s$	0.03
Water Rate, $l/m^2.s$	10
Suspended Solids Removal, %	75
Carbon column pumps (2):	
Capacity of each, l/s	28
Granular carbon columns (3)	
Hydraulic Loading Rate, $l/m^2.s$	2.9
Backwash Conditions	
Air Scour Rate, $l/m^2.d$	0.03

Water Rate, l/m^2/.d	10
Carbon Exhaustion Rate, g/m^3	120
BOD$_5$ Removal, %	80
Note: Number in parenthesis is the number of units or systems.	
Second dual media filters (2):	
Filtration Hydraulic Rate, l/m^2.s	1.4
Backwashing	
Air Scour Rate, m^3/m^2.s	.03
Water Rate, l/m^2.s	10
Ammonia exchange feed pumps (2):	
Capacity of each, l/s	28
Ammonia exchange columns (3):	
Hydraulic Loading Rate to tower, l/m^2.a	2.9
Clinoptilolite Capacity	
kg NH$_3$-N/m^3	3
kg NH$_3$-N/Column	41
Ammonia Nitrogen Loading Rate, kg/d	22.7
Ammonia Removal, %	95
Systems Serving Both Trains	
Chlorinators (2):	
Capacity of each, kg/d	181
Carbon regeneration system (1):	
Carbon Transfer to Drying Tank	
Hydraulic Rate, l/s	6.3
Carbon Transfer Rate, g/s	756
Moisture Content of Dried Carbon, %	45
Carbon Regeneration Furnace	
Loading Rate, kg carbon/d	1815

Operating Temperature, ^{o}C	930

Note: Number in parenthesis is the number
of units or systems.

Carbon Losses, %	5-10
Percentage Use, %	20
Ammonia exchange regeneration system (1):	
Brine Solution to Columns	
Hydraulic Rate, $l/m^2.s$	1.4
Volume, Bed Volumes	4.5
Strength, %	6
pH, units	10.5
Brine Solution Regeneration	
Hydraulic Loading Rate to Tower, $l/m^2.s$	4.8
Caustic Soda Added, g/g NH_3-N	3
Steam Quantity, g/s	428
Ammonia Recovery	
Aqueous Ammonia Strength, %	1
Aqueous Ammonia Volume, m^3	3.8
Sludge dewatering system (1):	
Amount of Sludge, kg/day	10-2200
Liquid Sludge Rate, maximum in l/s	5.4
Minimum Rate of Dewatering, g/s	38
Polymer Dosage, g/t	0.5
Dewatered Sludge Concentration, %	12-15

Note: Number in parenthesis is the number
of units or systems.

TABLE 2 — ROSEMOUNT DATA SUMMARY

APPENDIX B6/1

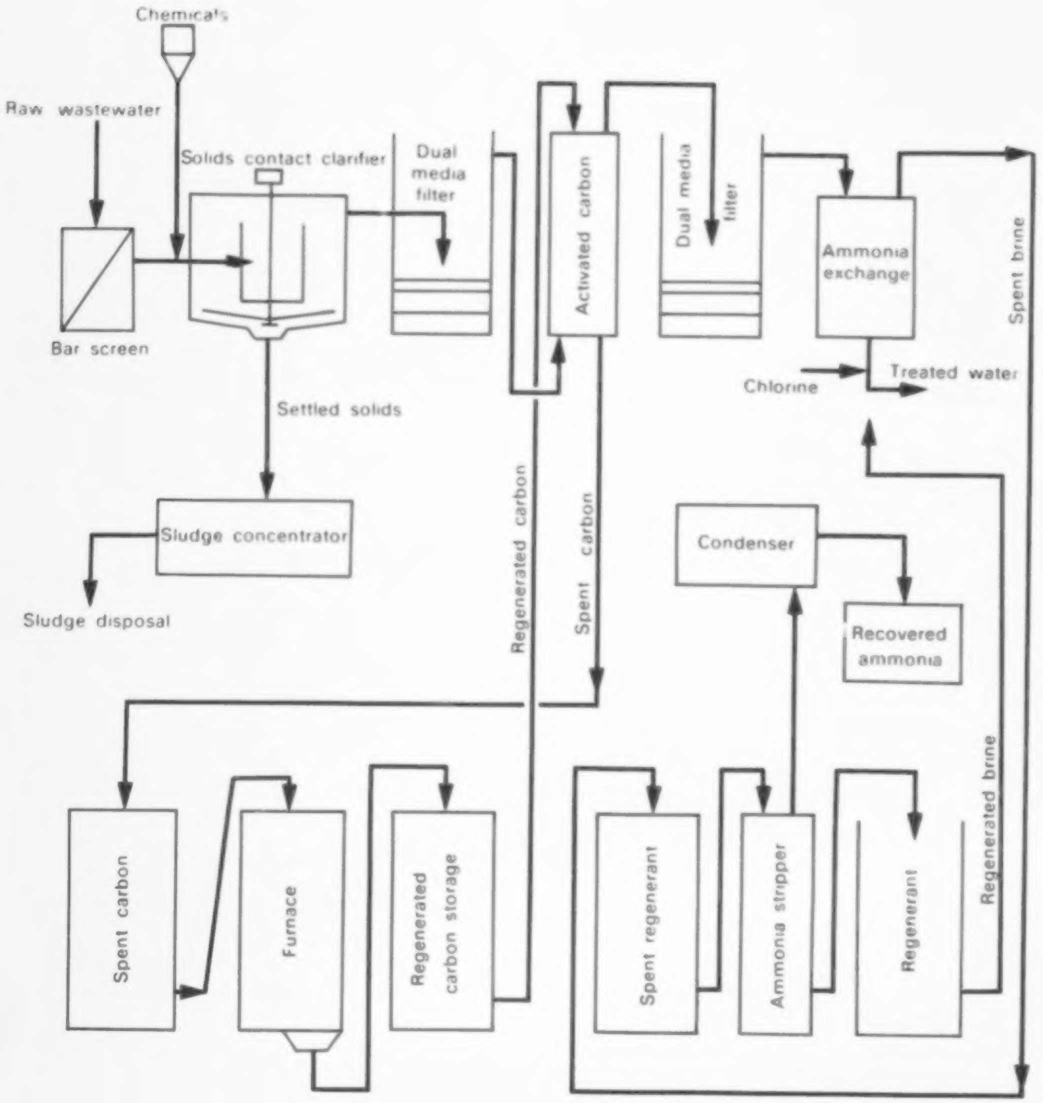
	C1	CE	F1	CCE	F2	IEE*	PE
pH	7.6	7.5	7.4	7.4	7.8	7.8	7.7
Suspended solids, mg/l	264	23	11.5	8.5	5.1		3.4
Turbidity — FTU		8	5	6	6		8
BOD_5 — total, mg/l	229	47	33	25	14		15
BOD_5 — filterable, mg/l	62	23		13			14
COD — total, mg/l	567	91	73	38	37		42
COD — filterable, mg/l	149	59	58	26			37
TOC — total, mg/l	105	25	21	12	11		13
TOC — filterable, mg/l	45	19	17	10			11
P — total, mg/l	13.7	1.2					1.0
P — total filterable, mg/l	9.8	0.6					0.6
NH_3-N, mg/l	37					8.4	24
Kjeldahl — N, mg/l	47	34				11.9	26

* Sampled only days zeolite columns in service

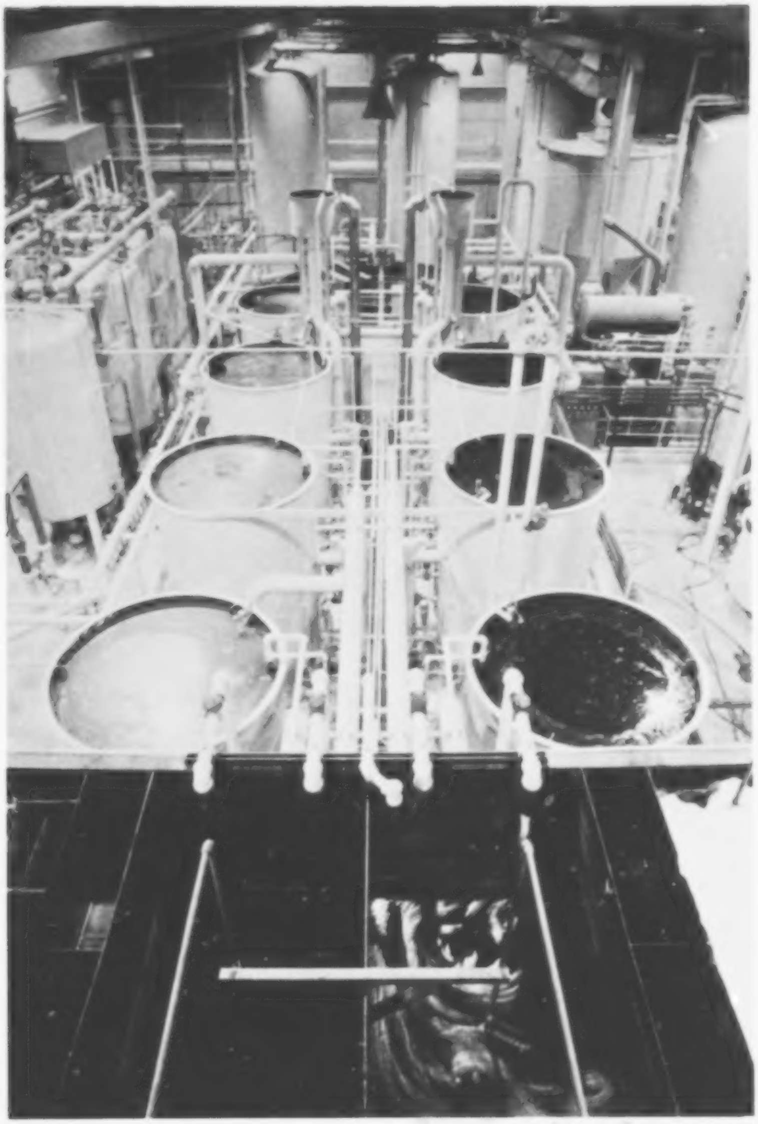
Legend:

C1	Clarifier influent
CE	Clarifier effluent
F1	First stage filter
CCE	Carbon column effluent
F2	2nd stage filter
1EE	Ion exchange effluent
PE	Plant effluent

Schematic of Rosemount, Minnesota Plant


Chemicals
Raw wastewater
Solids contact clarifier
Dual media filter
Bar screen
Settled solids
Sludge concentrator
Sludge disposal
Activated carbon
Dual media filter
Ammonia exchange
Spent brine
Chlorine
Treated water
Regenerated carbon
Spent carbon
Condenser
Recovered ammonia
Regenerated brine
Spent carbon
Furnace
Regenerated carbon storage
Spent regenerant
Ammonia stripper
Regenerant

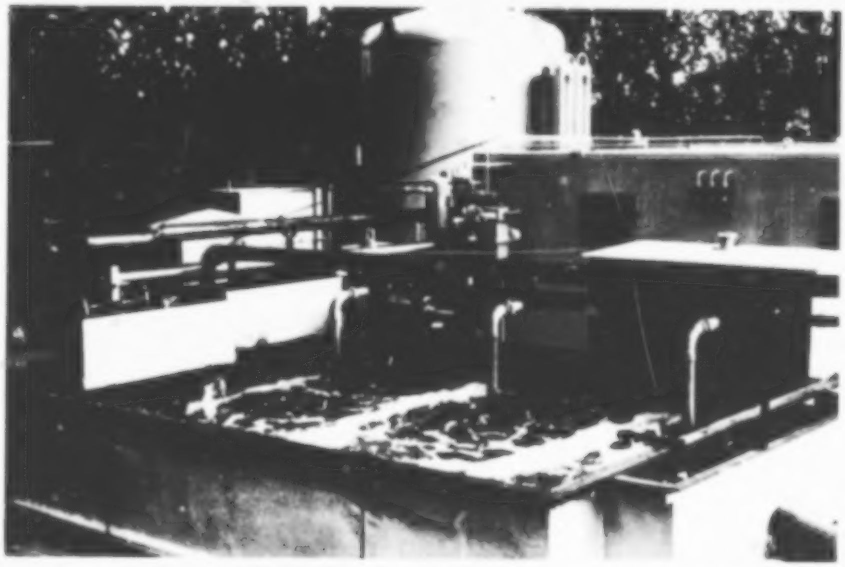
ROSEMOUNT, MINNESOTA, AWT – Dual train of 0.3 mgd each; clarification system on right, carbon columns on left.



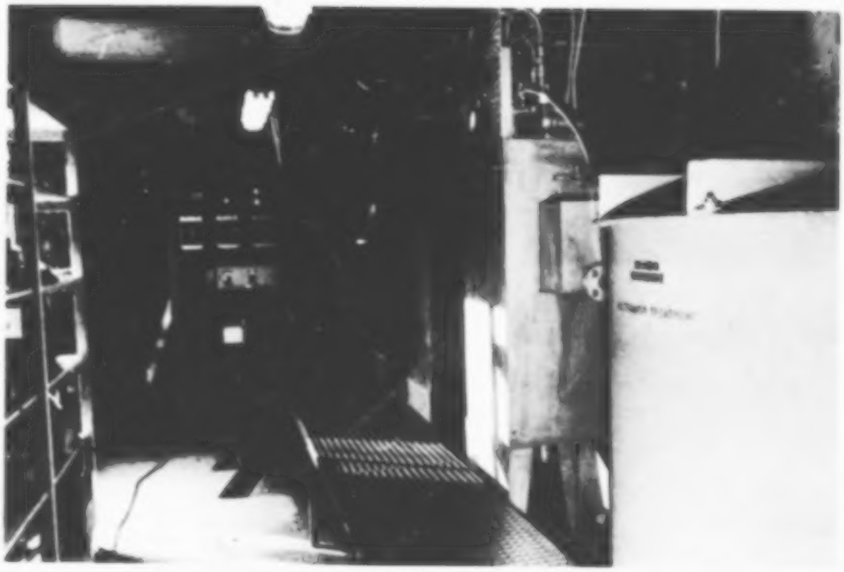
ROSEMOUNT, MINNESOTA, AWT – Dual trains of 0.3 mgd each consisting of chemical flocculation/coagulation and sedimentation.

Federal Republic of Germany

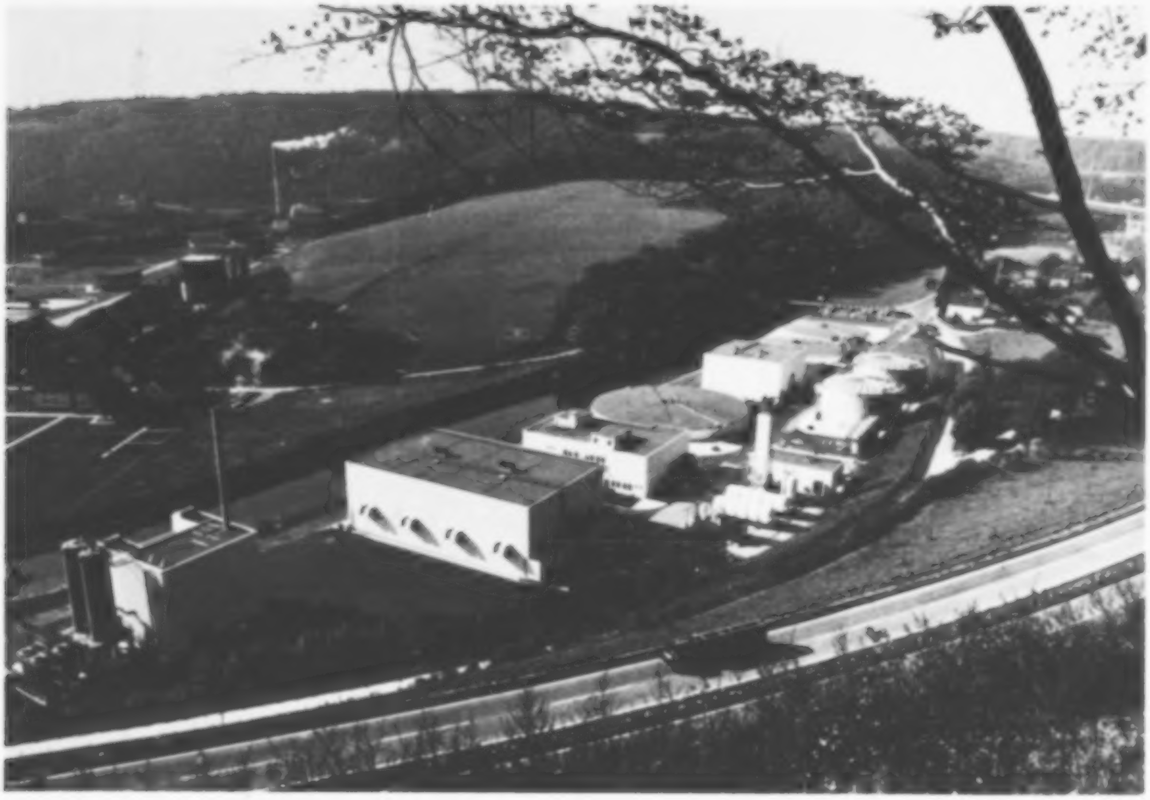
Photographs of plants referred to in section 7.4 of volume 1.



F.R. GERMANY — View of the test plant; the conventional plant with fine bubble aeration in the foreground, the Lindox-plant in the background.



F.R. GERMANY — Equipment of the pilot-plant at Wuppertal — Buchenhofen.



F.R. GERMANY – Two step oxygen activated sludge plant. Bayer A G , Wuppertal.

ADMINISTRATIVE

APPENDIX C

APPENDIX No.	TITLE
C1	International Advanced Wastewater Treatment (AWT) Group
C2	Definitions
C3	Project Management with United Kingdom
C4	Fig. 1 Early Project Management (1974) Fig. 2 Present Project Management (1978)
C5	United Kingdom AWT Committee Membership 1978.

International AWT Group

United Kingdom

Chairman
H S Tricker (to March 1974)
Director, Water Engineering 1

Roy Best (from March 1974)
Director, Research and Development Division
Water Engineering Directorate
Department of the Environment
2 Marsham Street
LONDON S W 1

Technical Secretary
Noel Banks (to February 1978)
Engineering Inspector, Research and Development Division

Richard Suriyadasa (from February 1978)
Engineering Inspector, Research and Development Division
Water Engineering Directorate
Room C4/15
Department of the Environment
2 Marsham Street
LONDON S W 1

Canada

Dr J D Salloum
Water Pollution Control Directorate
Environmental Protection Service
Environment Canada
OTTAWA

Federal Republic of Germany

Ministerialrat Dipl. Ing. H Muehleck
Bundesministerium des Innern
Rheindorfer Strasse 198
53 BONN 7

France

J M Bouchard (to 1975)
Ministère de la Qualité de la Vie Environnement

P R Philip (from 1975)
Ministère de la Qualité de la Vie Environment
14 Boulevard Général Leclerc
Pont de Neuilly
PARIS

Italy

Professor Ing. R. Passino
Consiglio Nazionale delle Richerche
Instituto di Ricerca Sulla Acque
Via Reno 1
ROME

Norway

Peter Balmer (to January 1978)
Norwegian Institute for Water Research

Dr Eikum (from January 1978)
Norwegian Institute for Water Research
Ganstadaleen 25
Box 333
Blindern
OSLO 3

United States of America

Dr Robert L Bunch
United States Environmental Protection Agency
National Environmental Research Centre
CINCINNATI
Ohio 45268

APPENDIX C2

Definitions

The following describe in popular terms what we mean by key words in the Report which are usually given more scientific definitions.

ADVANCED WASTEWATER TREATMENT (AWT) has no universally accepted definition but we have interpreted it in this Study as any process — or combination of processes — not usually used at operational wastewater treatment plants.

BIOCHEMICAL OXYGEN DEMAND (BOD). The amount of dissolved oxygen consumed by microbiological action when a sample is incubated, usually for five days at 20°C. Unless otherwise stated the BOD referred to in the text is BOD_5.

BREAK-POINT CHLORINATION. The addition of chlorine to a water to the point where thr free available residual chlorine increases in proportion to the incremental dose of chlorine being added.

CAPILLARY SUCTION TIME (CST). A measure of the filtrability of a sludge.

CAPITAL COST is the expenditure for which the benefit occurs over a long period of time.

CHEMICAL OXYGEN DEMAND (COD). The amount of oxygen consumed from a specified oxidising agent in the oxidation of matter present in a sample.

COST BENEFIT ANALYSIS (CBA) is the evaluation in monetary terms of all the consequences of a decision involving a comparison of the value in real terms (without any distortions) of benefits discounted to a base period with the value (also in real terms) of resources used to generate the benefits.

COST EFFECTIVENESS is either (i) Minimisation of the cost of resources used to achieve a given objective.
or (ii) Maximisation of output or service level with a given volume of resources.

DISCOUNTING is the reduction of the value of an item by a certain proportion related to the distance ahead of time.

DISSOLVED OXYGEN (DO). Oxygen dissolved in a liquid, the solubility depending on temperature, partial pressure and salinity.

EFFLUENT is the more liquid residue from wastewater treatment. It is usually subject to imposed discharge requirements.

GAS CHROMATOGRAPH MASS SPECTROMETER (GC/MS). A powerful analytical technique for the separation and identification of volatile organic substances; it is particularly well suited to the analysis of complex mixtures of organic compounds.

GRP is Glass Reinforced Plastic.

METHYLENE BLUE ACTIVE SUBSTANCES (MBAS). Used to detect substances sensitive to methylene blue and as an indicator of stability of an effluent.

MIXED LIQUOR. A mixture of settled sewage and activated sludge undergoing circulation and aeration in the aeration tank or channel of an activated sludge plant.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS). The weight of dry solids of mixed liquor in the aeration tank or channels of an activated-sludge plant.

MOST PROBABLE NUMBER (MPN). A statistical estimate of the numbers of viable bacteria present in a sample.

NPK is Nitrogen, Phosphorous, Potassium.

OPERATING COST is the expenditure for which the benefit accrues immediately or over a short period of time.

PHYSICAL/CHEMICAL TREATMENT (PCT) comprises processes or groups of processes in which chemicals are added specifically to complement or enhance the performance.

REDOX POTENTIAL. A measure of the state of oxidation of a system.

SLUDGE is the more solid residue from wastewater treatment. It can be complex and is not always subject to disposal constraints.

SLUDGE VOLUME INDEX (SVI). A rough measure of sludge settleability.

STANDARD TEMPERATURE PRESSURE (STP). A temperature of 273.15 Kelvins and 101325 Pascals.

SUSPENDED SOLIDS (SS). The undissolved solids, mainly organic, contained in wastewater.

TOC is Total Organic Carbon.

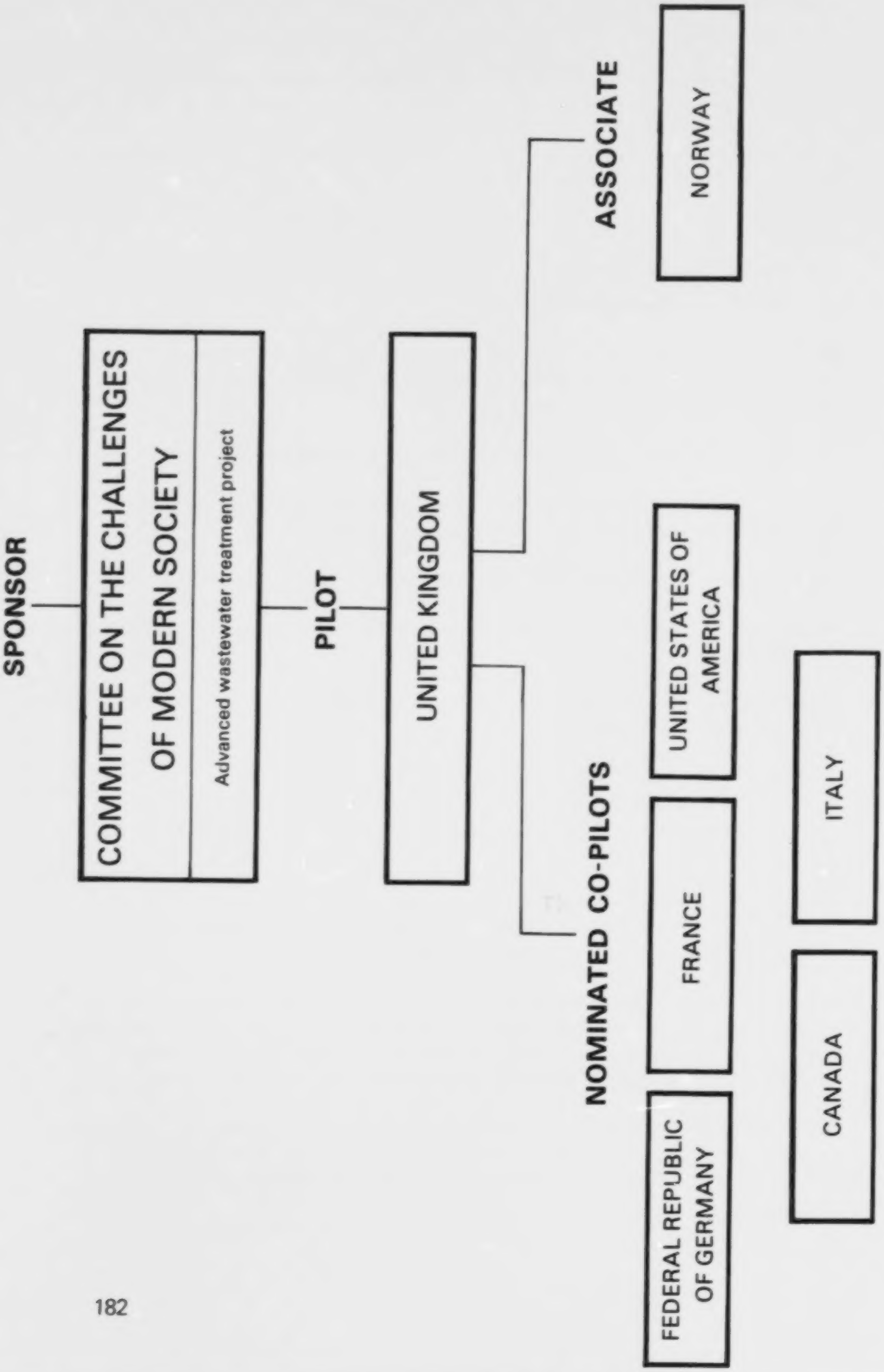
TOTAL KJELDAHL NITROGEN (TKN). A measure of the total organic nitrogen.

TRADITIONAL TREATMENT comprises processes or groups of processes normally used in publicly owned and managed operational plants and usually includes mechanical, physical, and biological stages.

WASTEWATER flows from the water-carriage sewerage system in which water is used to carry human wastes in pipes which may also convey surface water and liquid industrial wastes. (Wastewater is often popularly called Sewage and described as the liquid waste of an urbanised community).

WASTEWATER TREATMENT covers anything from removing some gross solids to producing a high quality effluent, possibly fit to drink. Normally it always involves separating solid from liquid and thus has more than one end product.

Appendix C3


SPONSOR
COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY
Advanced wastewater treatment project
PILOT
UNITED KINGDOM
ASSOCIATE
NORWAY
NOMINATED CO-PILOTS
UNITED STATES OF AMERICA
FRANCE
FEDERAL REPUBLIC OF GERMANY
ITALY
CANADA

PILOT/CO-PILOT STRUCTURE DEVELOPED

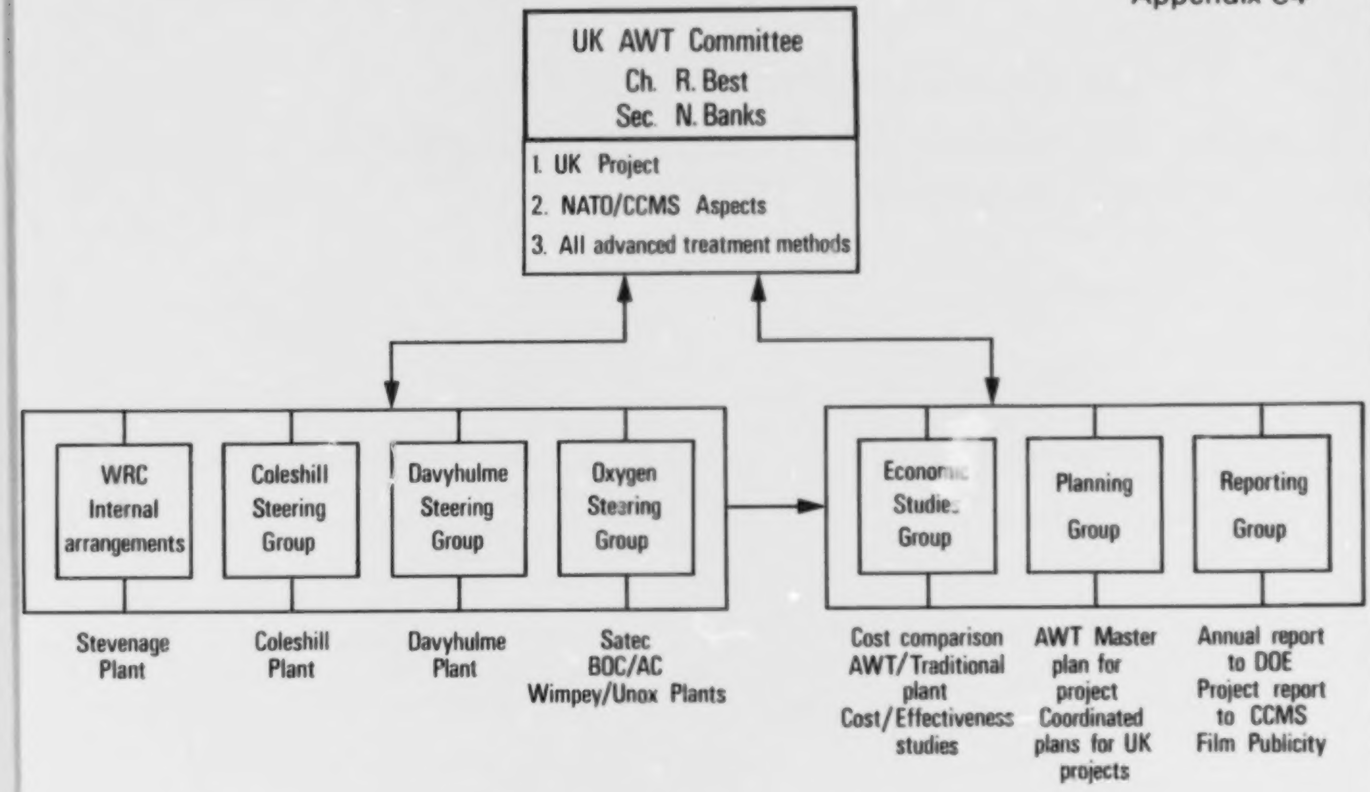
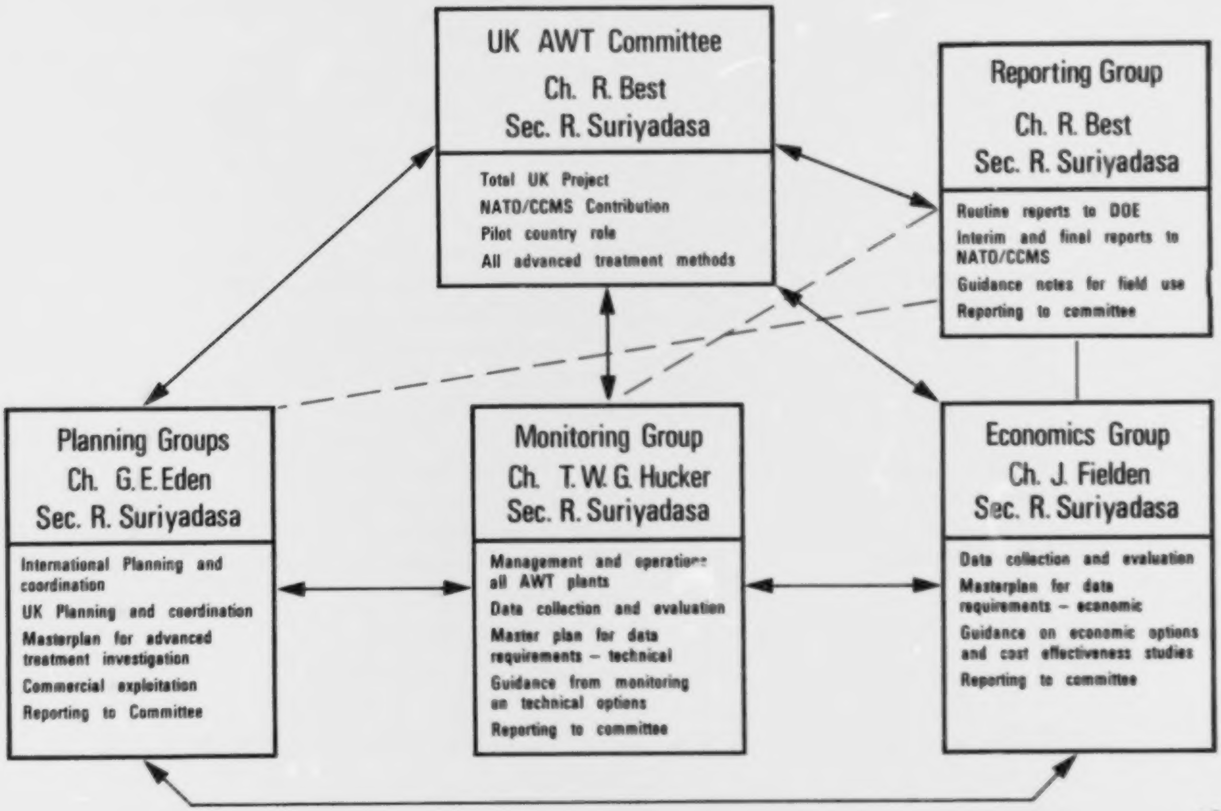

UK AWT Committee
Ch. R. Best
Sec. N. Banks
1. UK Project
2. NATO/CCMS Aspects
3. All advanced treatment methods
WRC Internal arrangements
Coleshill Steering Group
Davyhulme Steering Group
Oxygen Stearing Group
Economic Studies Group
Planning Group
Reporting Group
Stevenage Plant
Coleshill Plant
Davyhulme Plant
Satec BOC/AC Wimpey/Unox Plants
Cost comparison AWT/Traditional plant Cost/Effectiveness studies
AWT Master plan for project Coordinated plans for UK projects
Annual report to DOE Project report to CCMS Film Publicity

Fig. 1 Early Project Management (1974)


UK AWT Committee
Ch. R. Best
Sec. R. Suriyadasa
Total UK Project
NATO/CCMS Contribution
Pilot country role
All advanced treatment methods
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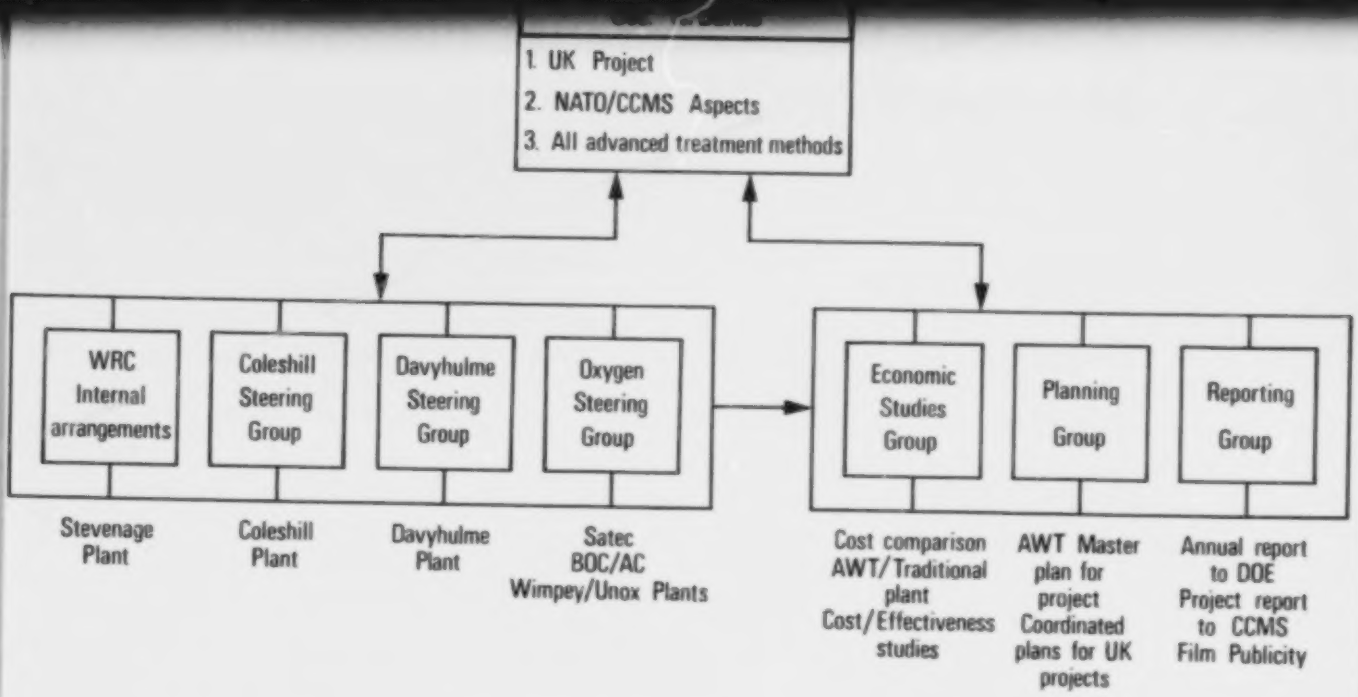
Ch. R. Best
Sec. R. Suriyadasa
Routine reports to DOE
Interim and final reports to NATO/CCMS
Guidance notes for field use
Reporting to committee
Planning Groups
Ch. G.E. Eden
Sec. R. Suriyadasa
International Planning and coordination
UK Planning and coordination
Masterplan for advanced treatment investigation
Commercial exploitation
Reporting to Committee
Monitoring Group
Ch. T.W.G. Hucker
Sec. R. Suriyadasa
Management and operations all AWT plants
Data collection and evaluation
Master plan for data requirements – technical
Guidance from monitoring on technical options
Reporting to committee
Economics Group
Ch. J. Fielden
Sec. R. Suriyadasa
Data collection and evaluation
Masterplan for data requirements – economic
Guidance on economic options and cost effectiveness studies
Reporting to committee

Fig. 2 Present Project Management (1978)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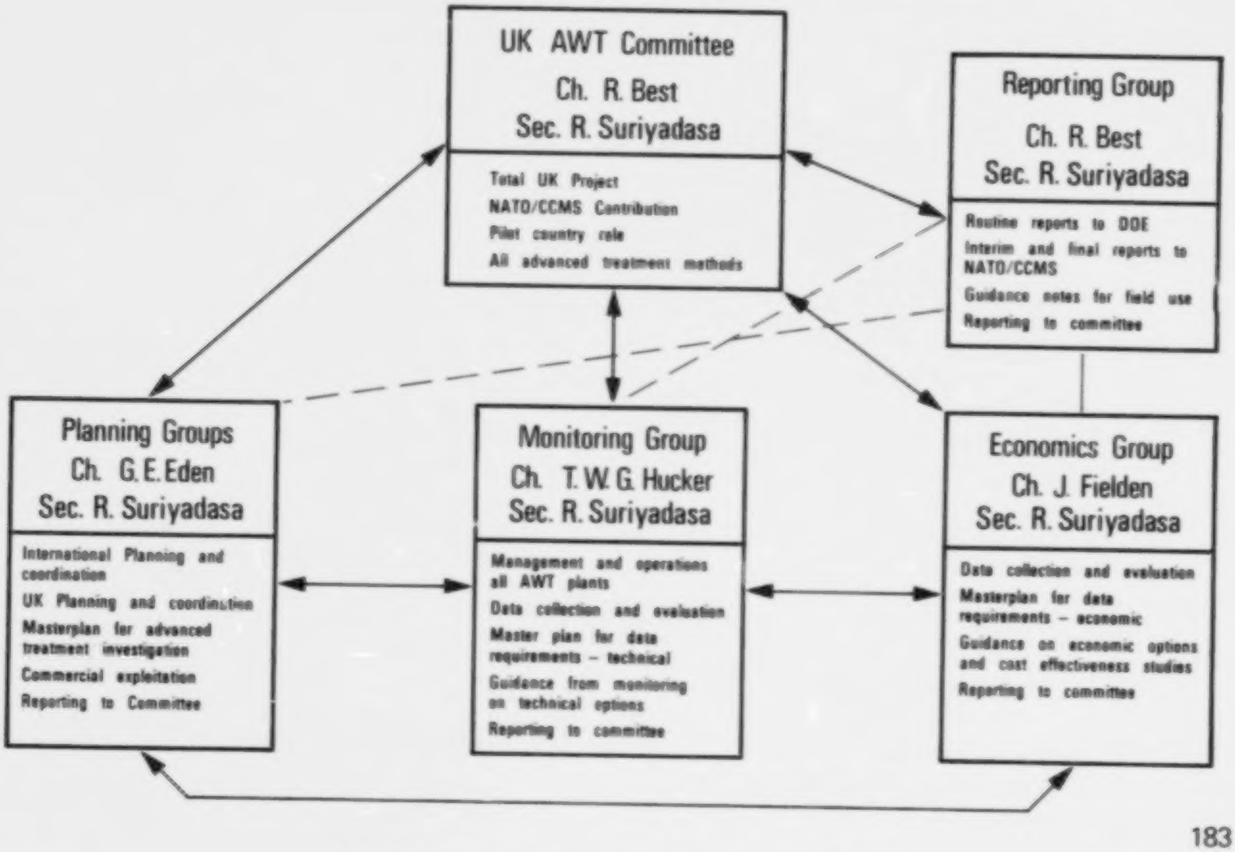
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Reporting to committee

Fig. 2 Present Project Management (1978)

United Kingdom Advanced Wastewater Treatment Committee Membership 1978

AWT Commitee

R Best — Water Engineering Directorate, DOE Chairman (ex officio-member of sub-committees)
R Suriyadasa — Water Engineering Directorate DOE, Technical Secretary
G Ainsworth — North West Water Authority (representing the Water Authorities)
D A Burroughes — British Water and Effluent Treatment Plant Association
R K Chalmers — Bostock Hill and Rigby Ltd (representing the Association of Consulting Scientists)
G E Eden — Water Research Centre (Stevenage Laboratory)
P H Garnett — Water Engineering Directorate DOE
T W G Hucker — Water Engineering Directorate DOE
Dr N J King — Central Unit on Environmental Pollution DOE
H R Oakley — J D and D M Watson (representing the Association of Consulting Engineers)
D A D Reeve — Severn-Trent Water Authority(representing the Water Authorities)
D C Renshaw — Directorate of Water DOE
G G Watson — Directorate of Research Policy DOE

Planning Sub-Committee

G E Eden — Water Research Centre, Chairman
R Suriyadasa — Water Engineering Directorate DOE, Technical Secretary
G Ainsworth — North West Water Authority
Prof. B Atkinson — University of Manchester, Institute of Science and Technology
R K Chalmers — Bostock Hill and Rigby Ltd
G F G Clough — Howard Humphreys & Sons
W F Lester — Severn-Trent Water Authority
N Schmidtke — Environment Canada
A B Wheatland — Water Research Centre (Stevenage Laboratory)

Monitoring Sub-Committee

T W G Hucker — Water Engineering Directorate DOE, Chairman

R Suriyadasa — Water Engineering Directorate DOE, Technical Secretary
M Booth — Coleshill Plant Manager
G S Clapham — Wessex Water Authority
P Cooper — Water Research Centre (Stevenage Laboratory)
Dr S H Jenkins — Bostock Hill & Rigby Ltd
J L Vosser — Water Engineering Directorate DOE
T Wallbank — Davyhulme Plant Manager
Dr M J D White — Water Research Centre (Stevenage, Laboratory)

Economics Sub-Committee

J Fielden — Peat Marwick Mitchell and Company, Chairman
R Suriyadasa — Water Engineering Directorate, DOE, Technical Secretary
R Barrass — Economics Environmental Protection DOE
R W Bayley — Water Research Centre (Stevenage Laboratory)
G F G Clough — Howard Humphreys & Sons
E Powell — Severn-Trent Water Authority

WATER AND DRAINAGE SITUATION IN MEMBER COUNTRIES

APPENDIX D

APPENDIX No.	TITLE
D1	Canada
D2	Federal Republic of Germany
D3	France
D4	Italy
D5	Netherlands
D6	Norway
D7	United Kingdom
D8	United States

Water and Drainage Situations in Member Countries — Canada

Water Supplies

1. Canada, with a population density of 2.3 persons per km^2, is blessed with abundant water. Industrial growth and settlements grew up around the major river systems, and melting snow and rainfall provide sufficient moisture to meet the needs of most farming regions.

2. Waterworks systems were developed during the 19th century and as the trend towards urban living progressed the majority of Canadians were served by these.

Sewerage Systems and Treatment

3. Sewerage systems equipped with proper treatment facilities developed more slowly and most municipalities poured their raw sewage into the nearest lakes or rivers from which, in many cases, their water supplies were drawn. In time provincial governments were forced to act and techniques were developed: primary treatment was generally carried out by some form of sedimentation process, while trickling filters and activated sludge systems were used for secondary treatment. But progress in waste treatment was slow. By 1972 about 90% of the urban population was served by sewage collection systems but only about 66% benefitted from some form of waste treatment. Significant sums of money are now spent annually on the construction of new waste treatment plants and in upgrading old ones. At the same time regulations have been formulated to ensure that industries treated their wastes, because uncontrolled discharge of industrial wastes is largely responsible for the seriousness of the water pollution problem in Canada.

4. *British Columbia* has a population of 2.5 million, of which 1.5 million are served by sewerage systems and treatment works. Most coastal communities practice primary treatment with effluent discharge to the sea. Waste stabilization ponds, activated sludge systems and their various process modifications are more commonly installed in the interior. Sludge drying beds and subsequent disposal to land-fills and/or farmers' fields are common.

5. *Prairie Provinces,* consisting of Alberta, Saskatchewan and Manitoba, have a combined population of 3.8 million and of these approximately 2.6 million are served with sewerage and connected to waste treatment systems. With the exception of major cities, most treatment systems consist of facultative lagoons. It is estimated that the sewered population produces 82,000 tonnes dry sludge annually.

6. *Quebec:* 5.5 of its 6.2 million population are served by sewers but only 400,000 by sewage treatment. Therefore the major emphasis is on ambitious construction plans for its major cities, Montreal and Hull.

7. *Atlantic Provinces* consist of Newfoundland, Prince Edward Island, Nova

Scotia and New Brunswick and have a population of 2.2 million of which 1.1 million are served by sewers; but only 360,000 by sewage treatment. With the exception of the city of Halifax, most cities are relatively small and treatment systems consist mainly of aerated lagoons and extended aeration systems. In many instances, because of the proximity of the Atlantic Ocean, discharge of effluents and sludge to the sea is practised.

8. *Ontario* has a population of 7.7 million, of which 6.5 million are served by sewerage. There are 310 sewage treatment plants with a total capacity of 4,368 x 10^3m_3/d; made up of 44 primary plants, 164 secondary plants and 102 lagoons. The largest is in Toronto and has a design capacity of 817 x 10^3m^3/d. Only 6% of the plants have a capacity greater than 45 x 10^3m^3/d and 71% have design capacities of 9 x 10^3m^3/d or less.

Pollution

9. It is the view of the Science Council of Canada that freshwater pollution is the environmental problem that demands most urgent attention in Canada today. Pollutants of Canadian inland waters which have attracted special attention are phosphates, now being controlled by the Great Lakes Agreement with the United States; heavy metals, particularly mercury, which occurs naturally in some areas at fairly high percentages and in agricultural chemicals which pollute lake waters receiving run-off. DDT is banned for nearly all purposes.

Two less usual water pollutants which are locally important are:

i. common salt, vast quantities of which are spread on Canadian roads in in winter;

ii. chemical and wood waste products from paper pulp mills, which have been the cause of eutrophication in some areas.

Thermal pollution of freshwater resources is also a potential problem. The solution to these problems is mainly financial; the cost of providing sewage treatment plants for the cities will cost thousands of millions of dollars and even upgrading existing sewage plants in the Great Lakes area to include phosphorus removal equipment will cost hundreds of millions.

10. With her huge reservoirs of freshwater and her recognition of the water pollution problem, at a relatively early stage in the development of much of her heavy and potentially polluting industry, Canada is in an enviable position with regard to management of her fresh water supplies.

Water and Drainage Situations in Member Countries — Federal Republic of Germany

Water Supplies

1. West Germany has 14000 independent water undertakings serving a population of 61.5 millions at a density of 249 persons per km^2. The undertakings fall into three main categories — the Private, semi-Private and Municipal Company — each of which may be responsible for water only, water and gas, or water, gas and transport etc. This structure appears to work satisfactorily and there are no plans for change.

2. The Federation is only entitled to create the frame within which the states fill in their own legislation and it is with the states that executive powers for legislation lies. Each Company is allowed to draw up its own conditions of supply but statutory regulations require all water supplies to be potable.

3. Groundwater is abstracted from many parts of Germany with little need for elaborate treatment; iron and manganese are removed by aeration and rapid filtration. In other areas, eg the Ruhr and Main valleys, natural gravels are used as a giant filter bed to purify river water; the process gives a naturally pleasant product although the low pH causes internal corrosion of pipes. Southern Germany has the benefit of pure water from mountain streams; and the region round Stuttgart is served by water abstracted from Lake Constance and the River Danube, which is treated by chemical flocculation, rapid gravity filters and chemical dosing before being pumped over hilly country to the various consumers.

Generally, provided the necessary new works are built and old ones extended, there is no great shortage of good quality water in Germany — except in Berlin which is a special case.

Pollution

4. Germany not only has to cope with her own pollution but with pollution imported by watercourses originating outside her borders. Pollution is also exported to other countries such as the Netherlands and Austria. Improvements of rivers and coastal waters is only possible through close international co-operation. In 1973 the European countries ratified an environmental action programme, and the principle that the originator was responsible.

5. In 1976, the riparian states of the Rhine agreed to reduce the volume of chemicals discharged, to take steps to reduce salinity, and determine permissable thermal pollution. However, measurable results in the reduction of water pollution have so far been relatively small, with a few exceptions — one of these is Lake Constance where the water quality shows a marked improvement.

Sewerage and Treatment

6. In 1969 about 17,400 x 10^3m^3/d of sewage and industrial wastes were discharged to public sewers and it is expected that by 1985 this volume will increase to about 26,000 x 10^3m^3/d.

7. Present day figures indicate that the combined sewerage contains 13% ground water, 50% domestic sewage and 37% industrial waste waters. 88% of the population are connected to sewers and some 61% of domestic sewage receives biological treatment. It is the Government's aim that by 1985 90% of the population will be connected to the sewerage system and all sewage will receive at least biological treatment.

8. In West Germany the chemical engineering technology in the field of wastewater treatment is seldom used in preference to mechanical biological wastewater technology. The process of wastewater treatment generally includes:

i. grit removal;
ii. primary treatment;
iii. a biological stage;
iv. final clarification;
v. sludge digestion; and
vi. drying beds

9. The choice of treatment process in the secondary treatment stage, which in the past was clearly related to the number of inhabitants in the community, has become more flexible since the development of such installations as the Essen tank. Biological filter installations are generally used for 10000-50000 inhabitants, and activated sludge method for 100,000-300,000 inhabitants upwards.

In a number of cases the combination of biological filtration and secondary aeration as the polishing stage has proved useful in some sewage plants for medium sized towns.

10. Permits for discharging wastewater are only granted when the quantity and noxiousness is kept as low as possible in accordance with commonly accepted rules of engineering, having regard to the minimum requirements issued by the Federal Government's regulations.

Water and Drainage Situations in Member Countries — France

Water Supplies

1. France is well endowed with water resources, only about 20% of which are being utilized. Rivers, the most used source of water, produce an estimated 175,000 cubic metres annually. The main problem is not quantity but quality, and in 1976 the Council of Ministers adopted a 15 year plan for restoring the quality of water flowing in rivers and streams by systematically neutralising domestic and industrial wastes and ensuring adequate flow in times of drought through the construction of more than 60 dams and reservoirs.

85% of the population have piped water supplies, and are served as follows: —

36% supplied by Compagnie Generale des Eaux

26% by 18 large undertakings

23% by other undertakings.

The water industry structure is based on six basins, each constituting a hydrographic zone; it is considered to work well and no changes are planned. It is claimed that all water supplied by the authorities is potable (with the exception of that supplied specifically for washing streets, etc). The water supplied is in fact fit for drinking and ozone treatment, which is widely used, is considered to give a safe and pleasant water though in some parts the water may have a taste. Mineral waters are often preferred and despite the purity of the normal water supply a lingering doubt exists.

2. In some towns 2 or 3 different kinds of water are supplied, eg potable, cleansing and irrigation water. Drinking water is prefiltered, flocculated, filtered, treated with ozone and desaturated.

3. The overal theoretical figure for consumption is taken to be 150 lhd; more accurately this figure represents the quantity a water authority must provide per head of the population served. Actual consumption varies between 210-500 lhd according to location.

Pollution

4. A substantial construction programme for water pollution plant is well in hand. Industries using a communal sewage system are being encouraged to instal purification systems. A national water purification and industrial effluent disposal programme is in progress. One of the problems is the present inadequacy of purification plant and inefficiency of collective sewers at coastal resorts and towns. Priority zones have been designated with the objective of complete elimination of water pollution and, in certain cases, purification of all industrial waste.

Special attention will be given to the protection of existing drinking water supplies, both underground and surface, unpolluted and lightly polluted water resources, freshwater shellfish cultivation areas, areas with seasonal tourist problems, and lakes. Specific measures will endeavour to reduce dumping or disposal of toxic waste, to eliminate illegal discharges and to instal early-warning devices on certain stretches of water. It is claimed that heavy pollution of rivers is prevalent in only a small area of the total supply. Sanctions against illegal pollution can be severe.

5. Though it is intended that quality objectives should be universal, there is at present no intention of formally setting objectives for all French waters. Efforts will be concentrated on particularly threatened drinking water supplies, lakes, and rivers important for fishing.

6. Efforts will be made to improve existing and develop new techniques of water purification, in particular for stations treating domestic wastewater, special attention to –

   i. high degree of purification of oxidisable organic matter;

   ii. elimination of certain substances, particularly nitrogenous material;

   iii. special factors such as noise and smell;

   iv. reliability and simplicity of operation.

Finally, emphasis will be put on the development of industrial processes which would make for more efficient use of water and reduce pollution.

Water and Drainage Situations in Member Countries — Italy

Introduction

1. In Italy the absence of a unifying body for the 2000-3000 water undertakings which serve the country makes it difficult to obtain a clear overall picture of the structure of the water industry. Rules and regulations vary between the various undertakings and it appears that the only rule which applies country-wide is the statutory requirement which demands that all water supplied shall be potable water (however, some hotels display notices saying that the water in the taps is not potable.) The most common danger of contamination of water supplies is considered to be from the use of lead and copper pipes.

2. 73% of the 47.5 million population are provided with piped water (that is 88% of the urban population; 61% of the population of the agglomerated communities; and 21% of the population of separate communities). Consumption varies from 410 lhd in Rome to between 30 and 50 lhd in the country.

3. Rome, Milan and other cities have large municipal undertakings; provincial undertakings serve groups of communes and small units supply 2 or 3 communes each. At the end of the scale in country areas the farmer, independent of any water undertaking, gets all the water he wants free of charge from his own well. In mountainous Apulia, where main laying is difficult and there is a shortage of water, the government constructed a complex but efficient water supply system.

4. Considerable effort is being made to bring the water supply and pollution control up to the standards of more advanced industrial nations, and large sums are being spent in the municipalities on treatment. The pollution of rivers and beaches is of great public concern from the points of view of public health authories and the tourist industry, consequently limits on concentrations of pollutants have been embodied in national water quality regulations for municipal and industrial wastewater. There is, however, a long way to go to achieve complete water pollution control in Italy and costs will play a large part in the rate of progress. To help meet the cost a law was approved by Parliament in 1976 which imposes on the industrialist the responsibility to build his own treatment works and to pay for public service in sewerage and final treatment (no subsidies or financial aid is available from government).

5. *Rome* has an ancient water system which is still used for non-potable supplies. Many houses have a private well, which must be sealed should a potable supply be provided. Water is abstracted from the River Tiber.

Domestic wastes are discharged into the River Tiber basin. Works in progress on the purification of the Tiber include the North Rome Sewage Treatment Plant to serve a population of 1 million (one third of Greater Rome): it is primarily a conventional plant employing centrifuging and incineration for the sludge. There are great problems in sewerage — one outlet to the Tiber is 2000 years old.

2 *Naples:* The 'Special Anti-pollution Project for the Gulf of Naples', started in 1971, covers a district whose floating population is estimated to reach 6 million by 1984 and a polluting load exceeding 15 million inhabitants. Pollution has been evaluated as being five times the national average. In 1974 and 1975 contracts were given for the construction of thirteen treatment plants: this huge set of works, which should be completed within 3 years, represents an expenditure of 350 billion lire out of a total anti-pollution programme of 500 billions foreseen for 1986.

3. *Genoa's* population of 800,000 obtains all its water from surrounding hills and adequate water is stored in a reservoir to bridge 3-4 month dry periods. The mountains come down to the sea and, therefore, the treatment of wastes has always been a problem. To overcome this 4 small works are being built on the coast and out to sea, they will be covered over and landscaped, and will each serve a section of Genoa. A typical plant, called Quarto-Quinto, is designed to serve a population of 52,000 and is able to treat a flow of 13,500 m^3 of water per day with a maximum capacity of 8,050 m^3/h. Initially screening is carried out to remove coarse particles, followed by sand separation, fine mechanical screening and oil removal in order that the sewage does not contain substances which may adversely affect the successive biochemical reaction. The pollution load is removed by a series of eight activated sludge units achieving a high rate oxidation process: it is hoped that an effluent a BOD_5 of 20 mg/l will be achieved. Final settlement is carried out in a rectangular tank providing for extended settling. Suspended solids standard will be 30 mg/l. The plant is completed with a sludge treatment system incorporating a filter press which enables the sludges to be removed at a concentration of 40% to a municipal incinerator and an ozone deodorising system for the environmental air. Discharge into the sea will be at 600 metres from the shoreline. A treatment plant is also being built on the inland side of Genoa to treat urban and industrial waste from a population of 195,000, equivalent to a mean flow of 2,900m^3/h. The first section will soon be operational and will treat a mean flow of 14,00m^3/h and a maximum flow of 1,750m^3/h of which 1,200 m^3/h will undergo further treatment in order to render it suitable for use in the local steelworks.

4. *Turin* obtains most of its water supply from river gravels, treatment plants deal with water abstracted from the river Po. There is a possibility that a reservoir will be constructed in the mountains.

5. The *Bari Modugno* industrial area in the South has a plant which incorporates the first tertiary treatment facilities built in Italy to provide reclaimed effluent waters for re-use by industry.

6. *Venice* has a population of about 140,000 during the tourist season and the adjacent town of Mestre has about 300,000. The modern practice of locating industry on a separate site has been followed for the past 40 years and the industrial area of Porto Marghera is on the mainland on the west side of the Lagoon of Venice. Even if biological purification of domestic sewage and industrial wastewaters were carried out to a high degree it is inconcievable that the lagoon will entirely cease to be eutrophic, because phosphate and nitrogen for algal growth will still be provided by purified sewage effluent and to a lesser extent by purified industrial effluent, agricultural run-off and river water. At present the cost of phosphate removal to a concentration which would prevent algal growth would be prohibitive. The only justification for removal of ammonia would be to reduce its oxygen demand during oxidation in the Lagoon. It is also questionable whether there is sufficient justification for nitrification until its purpose has been identified

and the need justified. A number of studies have been made on the contamination in the Venetian canals, which is substantially of domestic and commercial origin. Approaches to the problem of treating these flows, which are mainly from septic tanks, are under examination and it is reasonable to suppose that domestic waste pollution from this source will be substantially eliminated. One factor that contributes to pollution of the Lagoon is that pollutants discharged to it are retained within its confines for a long period. Some of the more common pollutants are controlled under Venetian law. These are mostly similar to the recommendations for the national laws.

Water and Drainage Situations in Member Countries — Netherlands

1. The Netherlands have a population of 13.8 million at a density of 409 persons/km^2; the total consumption of water per person varies between areas — e.g. it is 120 l/hd in Maastricht and 370 l/hd in Rotterdam. These figures include water used for both domestic and industrial purposes. The total supply of water for domestic and industrial purposes by the water supply undertakings amounted to 1085. $10^6 m^3$/year in 1976.

2. Some 96 municipal, provincial and governmental and 5 private undertakings supply the country with water — there is a movement towards reducing this number for the sake of greater efficiency. One third of the Netherlands' water is obtained from surface sources; it is not likely that this proportion will change in the course of time. The rivers Rhine and Meuse, which provide most of the surface water, are already polluted when they flow into the country.

3. Major pioneering work on water treatment is being carried out. In addition to the 525 existing water treatment installations in the Netherlands in 1977, a further 29 are under construction, and it is estimated that by 1980 Dutch water teatment capacity will be about 20.5 million pe, which will be close to saturation point.

4. Treatment plants with water jet aeration systems have been in use for some time. This system has the advantage that wastewater is amply supplied with oxygen and there is a thorough mixing of micro-organisms in the pond providing optimum conditions for biodegradability.

5. In 1977 there were 94 plants utilizing primary treatment only, 431 plants incorporating secondary treatment: now municipal sewage treatment facilities have been provided for 18 million population equivalents. From these about 7 million population equivalents are from industrial origin.

6. The system of secondary treatment in Holland has been influenced by the invention of oxidation ditch system by Pasveer. The biological systems presently in use are:

   a. 27% biological filters,
   b. 11% activated sludge plants,
   c. 62% oxidation ditches.

7. Sewage works are designed on a figure of 100-130 l/hd and typical domestic sewage contains 200-300 mg/l BOD_5.

8. Besides the municipal sewage treatment plants there are also 200 industrial waste water treatment plants in operation, corresponding to 5.3 million population equivalents.

Water and Drainage Situations in Member Countries — Norway

1. Norway has a small population — 4 million — and a plentiful supply of water. The water consumption per person is in the region of 450/500 litres per day. Water quality criteria and national effluent standards are not considered necessary: few industries discharge to the abundant freshwater and there are few cases of serious pollution.

2. The Ministry of the Environment administers planning, pollution and outdoor recreation. A national programme of sewage treatment works construction commenced in 1964; where STW receive industrial effluents charges, limits and agreements may be imposed.

3. Although there is central control of water pollution prevention, the control of domestic sewage in rural areas has recently been delegated to the 18 counties. The 450 'Kommunes' have similar powers and are responsible for the construction of STW, for which the counties issue building permits; permits to discharge are issued by the State Water & Sewage Office through the Ministry of the Environment. It is customary for STW to be enclosed, and the standard of management is high. The concentration of phosphate P in sewage effluents discharged to inland water and fiords is limited by permits in relation to eutrophication (no other constituent is usually limited). The permits incorporate limits on the load and concentration of phosphate P, together with a treatment specification.

   Mechanical-chemical or PCT is the usual method of treatment for sewage, but for small populations — around 500 — extended aeration combined with chemical treatment is considered more economical. There are few secondary biological treatment plants and these may have some form of tertiary chemical treatment.

4. Nutrients, particularly phosphates, are the prime problem, normally there is no lack of dilution. Chemically aided settlement gives effective reduction of phosphate, and the incidental reduction in BOD suffices to obviate any organic pollution problems in the receiving waters. The normal concentration of phosphate P as phosphorus in crude sewage is 5-6 mg/l. It is fairly low, probably because of infiltration water in the sewers. That concentration is usually reduced by PCT to less than 0.5 mg/l in the discharged effluent, ie about 90% removal.

5. It is considered cheaper to provide treatment for large flows of diluted sewage than to locate and repair leaks in sewers. Because of infiltration, crude sewages usually have BODs around 100-200 mg/l and melting snow causes further seasonal dilution.

6. In recently constructed STW, PCT usually consists of screening followed by degritting; the chemical is then added and a floc formed in primary settlement tanks; lastly, secondary settlement is given.

Water and Drainage Situations in Member Countries — United Kingdom

1. The United Kingdom has a population of 56 million persons of whom over 49 million live in England and Wales and 5 million in Scotland. The population density is 229 persons per square kilometre. Average daily consumption of water is about 310 litres per person per day of which one third is metered and supplied to industrial consumers.

2. The long term annual rainfall is 1090 mm with most rain falling in the west, least in the east. There is an increasing need to transfer water to urban areas.

3. In general, the south east part of the United Kingdom depends on underground abstraction for its water resources, and the north-west on surface storage in impounding reservoirs or lakes. London and a number of urban areas obtain their supplies by abstraction from rivers. Although there is no national grid it is possible to transfer water supplies from one region to another.

4. In 1974 ten water authorities were established in England and Wales to control all water activities in their hydrological region. In Scotland, Regional Councils carry out these duties with the exception of river management which is the responsibility of River Purification Boards.

5. There are 7800 sewage treatment works treating some 15 million cubic metres of sewage per day. Although there are 5 works serving over 1 million persons each, at the other end of the scale there are over 4000 works serving less than 500 persons each. About 1,000 works give primary treatment only and 750 give tertiary treatment by means of microstrainers, sand filters or sometimes grass plots to provide an effluent complying with a better than 30mg/1 suspended solids and 20mg/1 BOD_5 standard. The United Kingdom disposes of considerable quantities of its sewage and sewage sludge to the sea.

6. Screening, grit removal and primary settlement are treatment processes common to most works; most large works use the activated sludge process as the biological stage; humus, where biological filters are used, and surplus activated sludge being returned to primary settlement tanks for co-settlement with primary sludge. Smaller works however still rely on biological filtration.

7. In some lakes and rivers there has been a slow increase in nitrate content and it has been necessary to take precautions at certain times of the year, to prevent nitrate content rising in potable water. Where economical, regional sewerage and treatment schemes are replacing old works which served more confined areas; a process that has been made easier through the establishment of the Regional Water Authorities.

8. There is no requirement that phosphates be removed but nitrification is imposed where considered necessary by the imposition of an ammonia limitation on the effluent. Over 50% of sewage sludge is anaerobically digested.

Water and Drainage Situations in Member Countries — United States

Water Supplies

1. The United States is as rich in water as it is in many other resources and overall supply exceeds demand, but there is not necessarily enough water of the right quality wherever and whenever it may be needed: it can be provided in most cases but costs could be prohibitive. The population density is 27 persons per km^2, compared with 229 persons in the UK, and the demands on water resources are not noticeably greater than in the UK. The average annual streamflow in the 48 contiguous states is about 4,527,816 tcmd (1,200,000 mgd) — a rough measure of the potential water supply, nearly fourteen times the estimated water consumption in 1970.

2. During 1970 the United States abstracted 1,396,077 tcmd (370,000 mgd) of water from surface and ground sources to meet municipal, commercial, industrial and agricultural needs. Much of the water used is returned to streams and is available for re-use, but in 1970 nearly 25% of the water was consumed or lost through evaporation.

3. About 264,123 tcmd (70,000 mgd) of the water supply came from wells and springs and the remaining 1,131,954 tcmd (300,000 mgd) were taken from surface water sources of which some 203,752 tcmd (54,000 mgd) was saline water, that is containing more than 1000 mg/l of dissolved solids.

4. During 1965-1970 the use of water for public supplies increase by 13% to 101,876 tcmd (27,000 mgd). 70% of the public water supply was for domestic and public use, 30% being used by commerce and industry.

5. 170 million people, 84% of the population, now receive a piped water supply from a recognised water utility, of which there are some 30,000. 27,500 serve populations of 10,000 or less; the remaining 2,500 serving over 80% of those people on piped supply. In fact only 400 serve populations exceeding 100,000 persons and this group totals 77 million people.

6. 70% of utilities are publicly owned and serve 85% of those people on piped supply. Investor owned undertakings serve the balance of 15% (25 million people) but in all but two states these are regulated by public service commissions.

Water Quality

7. Lakes and rivers serve both as sewers and sources of drinking water for about half the population. In one survey of 155 cities, 144 were found to have "measurable traces of sewer effluent in the drinking water". An evaluation of community water supply systems conducted by the Department of Health, Education and Welfare in 1970, indicated that about 5% of the population is supplied with water which, failing to meet the mandatory Federal standards, is therefore potentially dangerous.

8. There has been public concern about the level of nitrates in drinking water but a recent report finds no evidence from present patterns of fertilizer use, that nitrates are a health hazard or danger to man, animal and the environment, though municipal waste and farm runoff appear to be factors in eutrophication. The report recommends more research into fertilizer use.

Pollution

9. The municipal water pollution position has scarcely improved over the past twenty years although about $15000m has been spent since 1952 on the construction of 7500 municipal sewage systems, industrial treatment plants and related facilities. Despite this, 1400 communities and cities still discharge their sewage untreated into the waterways. An equal number employ only primary treatment, partially removing some pollutants.

10. A major contributor to municipal water pollution is the combined storm water and sewage disposal systems in many cities, which, when overtaxed by heavy rains or snow, overflow and discharge the untreated combined sewage and storm water into the nearest waterway. The use of home garbage-disposal units further contributes to water treatment problems, since they double the output of solids and increase the biochemical oxygen demand of the household sewage. Thirteen hundred cities — including most older cities — still have combined foul and storm sewers and the American Public Works Association has calculated that the total public and private cost of separating existing storm and foul sewers would be some $48000m.

11. Hundreds of industrial premises still dump untreated wastes into public waterways and at least 300,000 plants discharge effluents into municipal sewage plants not equipped to process them. Industrial pollution includes oil and chemical discharges, and acid drainage and sediment from mines. Industrial outfalls into public waterways have grown with increasing production and with the introduction of more elaborate technological processes, so that more complex pollutants are being produced faster than methods are developed to combat them.

12. Thermal pollution causes a lack of oxygen in the source water, which is then unable to decompose certain organic substances or support fish and plant life and may be of reduced value to other users. New installations will account for more than half of the cooling water requirements of the power generating industry. It has been estimated that with the growing demand for electricity, one sixth of the annual freshwater runoff could be required for cooling by 1980.

13. Agricultural pollution stems largely from pesticides, herbicides, fertilizers and animal wastes from farms. One cow can produce pollution equivalent to that of 17 humans and animal waste now poses a disposal problem equivalent to that of almost ten million people. Irrigation runoff includes salts which might not otherwise have been leached from the soil. Greater use of fertilizers has increased the amount of nitrogen in water, and phosporus levels have risen since the 1950s when synthetic detergents replaced soap. Plant nutrients such as nitrogen and phosphorus support aquatic plants and in excess encourage dense algal growth, which promotes eutrophication. Pollution, suspected to be irreversible, of some ground water is also of concern, since this source already provides nearly a fifth of national requirements.

14. Recently water pollution has caused great public concern and an objective of 'clean waters' by 1985 has been set, backed by financial support for water and sewage treatment facilities to help meet the required standards.

15. *New York City's* water comes from as far as 211 km (125 miles) away, from 2 main water sheds: the Catskills and the Delaware water basins. 85% comes from the Croton Dam system located about 80 km (50 miles) north of the city. The system has 18 dams and aqueducts and supplies 5,600 tcmd (1.5 billion gallons per day); it is a generally protected watershed and is not filtered or treated — chlorine, fluorides and caustic soda only are added. There is a major distribution problem because there are only 2 tunnels (built in 1915 and 1936) into the city where a third is badly needed. Wastage of water through hydrant openings has been a problem but this, it is believed, is now under control. New York's water system is considered one of the major engineering achievements in Western civilisation. It operates on the gravity system from the source in the mountains right through to the City and does not therefore rely on pumps. There are 9650 km (6000 miles) of sewage pipes and 12 major treatment plants with 80% of the flow treated. Two more plants are needed. There is a 40 year programme for restoration of clean waterways and beaches: two major beaches, Coney Island and Staten Island have recently been reopened for bathing. There is a pilot upgrading scheme for 9 plants: the first pilot programme would bring the plant up to drinking water levels though there is no intention to use it as such. The City's major problem is the disposal of sludge and particular heavy metals. It produces 205 tonnes (200 tons) of sludge a day, which is at present disposed of at sea.

16. *Chicago* has a population of 7m in an area of 1166 km^2 (450 sq. miles.) It has 2 of the largest water treatment works in the world, the larger of these was built in Lake Michigan itself. The city is divided into 3 water districts. Water is drawn from the lake about 3.2 km (2 miles) off shore and poses little difficulty in treatment, other than taste on occasion. The nominal output rate of the Central Water Plant is 3622 tcmd (960 mgd), that of the South District Plant, 1207 tcmd (320 mgd); US gallon = 5/6 UK gallon). Treated water storage is less than one days usage so that system reliability is most important. Supply averages about 943 l/person/day (250 galls/person/day in the city). Chicago claims to have the world's largest sewage treatment complex, Chicago Metropolitan Sanitary District, and is now undertaking a $2,000 million plan to handle storm water storage and treatment to be followed by a flood control scheme. Work on the first phase involves 145 km (90 miles) of 2.75m (9ft) to 10.68m (35ft) diameter tunnels drilled through rock 46m (150ft) to 92m (300ft) below ground. When work is completed, runoff from rainstorms (now up to 30 times capacity of existing storm water sewers) will be stored in the tunnel system and 3 abandoned quarries. The combined sewage (foul and storm water) will be pumped through existing conventional sewage treatment works during dry weather conditions. The District has 3 main sewage treatment works with a designed capacity of 4528 tcmd (1.2 billion gpd); they produce a total of about 1016 tonnes (1,000 tons) of digested sludge solids each day. Since 1966, a programme has been in hand to return sludge to the land as liquid fertiliser and soil conditioner. By this means strip-mined land could be converted to productive agricultural land.

17. *Detroit's* Municipal Water System serves a population of about 4 million of whom nearly 2 million live in suburban towns. The main source of supply is direct abstraction from the Detroit River which has supplied over 3773 tcmd (1,000 mgd) on peak days through 3 main water treatment works. Treatment

is full coagulation, sedimentation, high rate filtration, disinfection and taste/odour control. The city has plans to develop an additional source and are uprating their treatment works. The water supply has ample capacity and meets all water quality standards.

Sewage from Detroit City and 76 surrounding communities is handled by one large sewage treatment works near Detroit. At present, sludge containing 163 tonnes (160 tons) of dry solids is incinerated daily. For years, Detroit's sewage treatment works has been unable to incinerate all its sludge, and much of it has been released into the Detroit River in violation of Federal regulations. They are studying the feasibility of transporting liquid sludge by rail to Lake City to use as fertilizer.

18. *Washington DC* water supply (collection and treatment of water) is under the control of the Department of the Army whereas the distribution system is owned and operated by the District of Columbia. The population supplied is about 1½ million. The source of water is the Potomac River from which water is abstracted and stored in Dalecarlia Reservoir. Sewage is treated in a 981 tcmd (260 mgd) activated sludge treatment works at Blue Plains and the effluent is returned to the Potomac River. Sludge is disposed of by landfill and landspread. The system is being converted to advanced treatment to meet stringent Federal quality standards for effluent.

Eutrophication of the Great Lakes

19. The Great Lakes and St Lawrence River comprise one of the great water systems which drain the North American continent towards the east shores. The International Joint Commission monitors the Lakes and makes orders under authority of the Government of the USA and Canada concerning regulations for the Lakes system.

20. Pollution of the Lakes comes from many sources — effluents from sewage treatment works, combined sewage discharges, industrial wastes inadequately treated, dredging of harbours and channels for shipping, agricultural runoff and sub-surface waste disposal in porous strata. These have combined to produce eutrophic conditions and the problem is not whether the process can be reversed but whether it can be suspended at the present level.

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APPENDIX No.		TITLE
E1		REFERENCES
	E1/1	Physical-Chemical Treatment
	E1/2	Filtration
	E1/3	Activated Carbon
	E1/4	Activated Carbon Regeneration
	E1/5	Direct Oxygen Application
	E1/6	Other Advanced Treatment Processes

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